Physical Activity in Adolescents —
Barriers and Impact on Depressed Affect

Dissertation
der Mathematisch-Naturwissenschaftlichen Fakultät
der Eberhard Karls Universität Tübingen
zur Erlangung des Grades eines
Doktors der Naturwissenschaften
(Dr. rer. nat.)

vorgelegt von
Nadine Langguth
aus Lübeck

Tübingen
2016

Gedruckt mit Genehmigung der Mathematisch-Naturwissenschaftlichen Fakultät der Eberhard Karls Universität Tübingen.

Tag der mündlichen Qualifikation:	11.04.2016
Dekan:	Prof. Dr. Wolfgang Rosenstiel
1. Berichterstatter:	Prof. Dr. Caterina Gawrilow
2. Berichterstatter:	Dr. Gertraud Stadler

Acknowledgments

Mein herzlicher Dank gilt allen, die zum Gelingen dieser Doktorarbeit beigetragen haben.

Insbesondere gilt mein Dank meinen beiden Doktormüttern Prof. Dr. Caterina Gawrilow und Dr. Gertraud (Turu) Stadler. Caterina Gawrilow danke ich dafür, dass sie mir die Möglichkeit gegeben hat, in Frankfurt zu forschen und in Tübingen zu promovieren. Auch möchte ich mich bei ihr für ihre Unterstützung auf allen Etappen meiner Promotion bedanken. Turu Stadler danke ich dafür, dass sie mich vor vielen Jahren als Studentin an das wissenschaftliche Arbeiten herangeführt und mit mir ihre Begeisterung für Forschung geteilt hat. Auch möchte ich ihr dafür danken, dass sie mir bei allen Schritten auf dem Weg zur Promotion, insbesondere bei der Datenauswertung und dem Verfassen der Manuskripte, immer mit Rat und Tat zur Seite stand.

Der Stiftung Polytechnische Gesellschaft Frankfurt am Main, insbesondere Herrn Dr. Wolfgang Eimer und Herrn Tobias Ullrich vom MainCampus Stipendiatenwerk, danke ich von Herzen für die finanzielle Unterstützung und persönliche Begleitung im Rahmen meines doctus-Stipendiums und darüber hinaus.

Meinen Kolleginnen Tanja Könen und Johanna Schmid (IDeA-Zentrum, DIPF) sowie Simone Matulis und Regina Steil (Universität Frankfurt) danke ich herzlich für ihr großes Engagement und ihren immerwährenden Zuspruch. Darüber hinaus möchte ich meiner Kollegin Jule Albert (IDeA-Zentrum, DIPF) herzlich für den kollegialen Zusammenhalt danken. Mein besonderer Dank gilt "meinen Studentinnen", die mich im Rahmen ihrer Abschlussarbeiten mit viel Einsatz, Leidenschaft und großer Zuverlässigkeit bei der Studiendurchführung und Dateneingabe unterstützt haben: Danijela Bacic, Giulia Capudi, Magdalena Eich, Hanna Fray, Hannah Jöckel, Corinna Jung, Lea Köhler, Marie Landenberger, Lena Löffler, Laura Loos, Susan Manzke, Katrin Molsen, Verena Noel, Annika Plambeck, Sarah Seitz und Ebru Sümen.

Meinen Freunden Anke, Diana, Franziska, Gabriella, Hilke, Katharina, Johanna, Nina, Svenja und Tanja möchte ich dafür danken, dass sie immer an mich geglaubt und mich ermutigt haben, auch und gerade in schwierigen Zeiten. Das werde ich euch nicht vergessen.
Johanna danke ich darüber hinaus herzlich für ihr leidenschaftliches und sehr sorgfältiges Korrekturlesen.

Von ganzem Herzen danke ich Tanja Boelicke – sie weiß wofür.

Mein letzter und größter Dank gilt Flo, dem ich diese Arbeit widmen möchte. Ohne seine jahrelange Rücksichtnahme und seinen Verzicht, seinen unermüdlichen Rückhalt, seinen Glauben an mich und seine Liebe hätte ich diese Arbeit nicht beendet.

List of Publications

This dissertation is based on the following three manuscripts:

I. Langguth, N., Könen, T., Matulis, S., Steil, R., Gawrilow, C., & Stadler, G. (2015). Barriers to physical activity in adolescents: a multidimensional approach. *Zeitschrift für Gesundheitspsychologie, 23*, 47–59. doi:10.1026/0943-8149/a000136

II. Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2016). Physical activity, affect, and cognition in children with symptoms of ADHD. *Journal of Attention Disorders, 20*, 151–162. doi:10.1177/1087054713493318
This manuscript includes two studies. I was only involved in Study 1.

III. Langguth, N., Schmid, J., Gawrilow, C., & Stadler, G. (2016). Within-person link between depressed affect and moderate-to-vigorous physical activity in adolescence: an intensive longitudinal approach. *Applied Psychology: Health and Well-Being, 8*, 44–63. doi:10.1111/ aphw.12061

List of Tables

List of Figures

List of Abbreviations

ADHD	Attention-deficit/hyperactivity disorder
APA	American Psychiatric Association
CBCL	Child Behavior Checklist
CES-D	Center for Epidemiologic Studies Depression Scale
CFA	Confirmatory factor analysis
CFI	Comparative fit index
DSM-5	Diagnostic and Statistical Manual of Mental Disorders, 5th edition
EFA	Exploratory factor analysis
HAPA	Health Action Process Approach
HBM	Health Belief Model
ICD-10	International Classification of Diseases, 10th edition
IPAQ	International Physical Activity Questionnaire
IPAQ-LF	International Physical Activity Questionnaire – Long Form
IPAQ-SF	International Physical Activity Questionnaire – Short Form
MAACL	Multiple Affect Adjective Checklist
ML	Maximum likelihood
MVPA	Moderate-to-vigorous physical activity
PANAS-X	Positive and Negative Affect Schedule
POMS	Profile of Mood States
POMS-15	Profile of Mood States, 15-item version
RCT	Randomized controlled trial
RMSEA	Root mean square error of approximation
SCT	Social Cognitive Theory
SDQ	Strengths and Difficulties Questionnaire
SRMR	Standardized root mean square residual
TPB	Theory of Planned Behavior
TRF	Teacher's Report Form
TTM	Transtheoretical Model of Change
WHO	World Health Organization
YSR	Youth Self-Report

List of Contents

Abstract

Adolescence is a high-risk period for physical inactivity as well as depressed affect, both related to various short-, mid-, and long-term negative consequences for adolescents' physical and mental health. Therefore, this developmental period is ideally suited for studying the association between change processes of everyday physical activity and change processes of depressed affect within person by applying an intensive longitudinal design. Given that physical activity substantially decreases during adolescence, researchers are working hard to better understand what actually impedes adolescents' physical activity participation. The present dissertation is based on three manuscripts and focuses on the nature and many facets of adolescents' barriers to physical activity, culminating in the development of a valid questionnaire for measuring multiple dimensions of barriers that can impede adolescents' physical activity participation most. Moreover, this dissertation aims to examine the within-person association between adolescents' daily everyday physical activity and depressed affect among adolescents with varying levels of vulnerability for elevated depressed affect (e.g., hyperactivity). Deeper insight into adolescents' barriers to physical activity and the temporal within-person associations between their everyday physical activity and depressed affect seems to be an important prerequisite for developing targeted, tailored interventions that enable adolescents to manage their most impeding barriers to physical activity in order to increase their physical activity and, thereby, reduce their depressed affect. However, despite the apparent relevance of both research topics for adolescents' general physical and mental health, data are still sparse. The aim of this dissertation is to make a contribution towards narrowing these research gaps.

Manuscript I addresses barriers to adolescents' physical activity. To date, this is the only publication that investigates the dimensional structure of barriers to physical activity in adolescents by applying both a qualitative and a quantitative approach. In Study 1 (qualitative study, item development), adolescents self-generate those barriers that impede their everyday physical activity most. Based on the categorization of 602 barrier items by two coders, 46 most commonly cited barriers to physical activity that should cover a broad range are selected for Study 2. In Study 2 (quantitative study, questionnaire validation), as a first step, we conduct an exploratory factor analysis (EFA) using Mplus which provides the opportunity to interpret EFA results by means of established continuous fit indices (χ^2, CFI, RMSEA, and SRMR). Item selection (25 out of 46 items) is based on these EFA results. A seven-factor model (leisure activities, lack of motivation, screen-based sedentary behavior, depressed mood, physical health, school workload, and preconditions) is the first model that shows an acceptable fit in all indices. As a second step, we conduct a confirmatory factor analysis (CFA) to test the seven-factor solution of the EFA and evaluate the model fit by using the χ^2 test, CFI, RMSEA, and SRMR. Taken together, results indicate that a multidimensional approach for measuring adolescents' barriers to physical activity is valid within our sample and is more appropriate than uni- or two-dimensional approaches, which were predominately applied in prior research.

Study 1 of Manuscript II focuses on the within-person association between everyday physical activity (steps per day measured through pedometers) and same-evening depressed affect among adolescents and examines, as one of very few studies, whether higher levels of hyperactivity moderate this link. Results show that on days with higher-than-usual physical activity (i.e., more steps per day) adolescents experience less evening depressed affect than on days with lower-than-usual physical activity. As expected, this within-person physical activity–depressed affect link is stronger in adolescents with higher levels of hyperactivity. On a given day, with a 1-unit increase in physical activity (i.e., an additional 10,000 steps taken per day) above the within-person mean, adolescents' depressed affect decreased to almost zero ("not at all").

Manuscript III targets the within-person association between everyday physical activity (determined by minutes spent with moderate-to-vigorous physical activity (MVPA), per day measured by accelerometers) and next-morning and same-evening depressed affect among adolescents and, thus, supplements Study 1 of Manuscript II. However, Manuscript III exceeds Manuscript II with respect to sample size, measurement of physical activity (accelerometers instead of pedometers) and frequency of assessing depressed affect (twice instead of once per day). Moreover, as opposed to Manuscript II, Manuscript III investigates gender and day of the week (i.e., weekday versus weekend day) as moderators of the within-person link. Results indicate that for young women on weekdays, a 60-minute increase in MVPA above the within-person mean predicts a 50% decrease in next-morning depressed affect. There is no such time-lagged predictive relationship regarding MVPA on weekend days or among young men. Moreover, there was no within-person association between MVPA and evening depressed affect (same-day link).

Based on the results of the three manuscripts, the present dissertation highlights the importance of (a) considering multiple, diverse barriers to physical activity relevant to adolescents in health research and practice (with respect to the development and improvement of targeted intervention strategies to enhance adolescents' physical activity) and (b) systematically examining naturally occurring time-lagged or same-day change processes under everyday conditions to gain a better understanding of the association between adolescents' physical activity and depressed affect within person. In addition, results from Manuscripts II and III illustrate the great potential of everyday physical activity for alleviating depressed affect among adolescents on a day-to-day basis. However, further research is needed to replicate the results of this dissertation.

Zusammenfassung

Das Jugendalter ist eine Entwicklungsphase, die durch ein hohes Risiko für Bewegungsmangel und depressiven Affekt gekennzeichnet ist. Sowohl Bewegungsmangel als auch depressiver Affekt sind mit zahlreichen kurz-, mittel- und langfristigen negativen Konsequenzen für die körperliche und psychische Gesundheit von Jugendlichen verbunden. Deshalb ist das Jugendalter besonders gut geeignet, um mögliche intraindividuelle Zusammenhänge (d.h. Zusammenhänge innerhalb einer Person) zwischen Veränderungen der körperlichen Aktivität im Alltag und Veränderungen des depressiven Affekts im Rahmen von intensiven Längsschnittstudien zu untersuchen. Vor dem Hintergrund, dass körperliche Aktivität im Verlauf des Jugendalters erheblich abnimmt, arbeiten Wissenschaftler intensiv daran, besser zu verstehen, was Jugendliche tatsächlich daran hindert, körperlich aktiv zu sein. Die vorliegende Dissertation basiert auf drei Manuskripten und widmet sich der Art und der Vielfalt von Barrieren körperlicher Aktivität von Jugendlichen sowie der Entwicklung eines validen Fragebogens zur mehrdimensionalen Erfassung von Barrieren, die Jugendliche darin hindern können, körperlich aktiv zu sein. Des Weiteren widmet sich diese Dissertation der Untersuchung des intraindividuellen Zusammenhangs zwischen körperlicher Alltagsaktivität und depressivem Affekt bei Jugendlichen im Allgemeinen sowie im Speziellen bei Jugendlichen, die sich in ihrer Vulnerabilität für depressiven Affekt unterscheiden, d.h., die ein unterschiedliches Ausmaß an Hyperaktivität aufweisen. Barrieren körperlicher Aktivität und die zeitlichen intraindividuellen Zusammenhängen zwischen körperlicher Aktivität und depressivem Affekt von Jugendlichen im Alltag besser zu verstehen, stellen wichtige Voraussetzungen für die Entwicklung gezielter, individuell zugeschnittener Interventionen dar, die Jugendlichen dabei helfen können, Barrieren zu überwinden, ihre körperliche Aktivität zu steigern und dadurch ihren depressiven Affekt zu verringern. Trotz der offensichtlichen Relevanz der beiden Forschungsthemen für die körperliche und psychische Gesundheit von Jugendlichen, ist die Datenlage dazu noch spärlich. Das Ziel dieser Dissertation besteht darin, einen Beitrag dazu zu leisten, diese Forschungslücken zu verringern.

Manuskript I beschäftigt sich mit Barrieren körperlicher Aktivität von Jugendlichen. Bisher ist diese Publikation die einzige, die die dimensionale Struktur von Barrieren körperlicher Aktivität bei Jugendlichen untersucht, indem sie sowohl einen qualitativen als auch einen quantitativen Forschungsansatz verfolgt. In Studie 1 (qualitative Studie, Itementwicklung), benennen Jugendliche die Barrieren, die sie aus ihrer Sicht am stärksten daran hindern, körperlich aktiv zu sein. Auf der Grundlage der Kategorisierung von 602 Barrieren-Items durch

zwei Kodierer, werden 46 der am häufigsten angeführten Barrieren körperlicher Aktivität, die zudem ein möglichst breites Spektrum abdecken sollen, für Studie 2 ausgewählt. In Studie 2 (quantitative Studie, Fragebogenvalidierung), führen wir in einem ersten Schritt eine explorative Faktorenanalyse (EFA) mittels Mplus durch (unter Heranziehung der Fit Indices χ^2, CFI, RMSEA, und SRMR zur Beurteilung der EFA-Ergebnisse). Die Auswahl von 25 der ursprünglich 46 Items basiert dabei auf den EFA-Ergebnissen. Ein Sieben-Faktoren-Model (Freizeitaktivitäten, mangelnde Motivation, Medienkonsum, depressiver Affekt, körperliche Gesundheit, schulische Arbeitsbelastung und Voraussetzungen) zeigt als erstes der untersuchten Modelle einen akzeptablen Fit in allen Indizes. In einem zweiten Schritt, führen wir eine konfirmatorische Faktorenanalyse (CFA) durch, um das Sieben-Faktor-Model aus der EFA zu überprüfen und die Anpassungsgüte erneut unter Heranziehung der Indizes χ^2-Test, CFI, RMSEA und SRMR zu untersuchen. Zusammengefasst zeigen die Ergebnisse, dass ein mehrdimensionaler Ansatz für die Erfassung von Barrieren körperlicher Aktivität bei Jugendlichen in unserer Stichprobe valide ist und dazu noch deutlich besser geeignet erscheint als ein- oder zweidimensionale Ansätze, die in vorherigen Studien fast ausschließlich angewendet wurden.

Studie 1 von Manuskript II befasst sich mit dem intraindividuellen Zusammenhang zwischen körperlicher Alltagsaktivität (Schritte pro Tag, erfasst durch Schrittzähler) und depressivem Affekt am Abend bei Jugendlichen und untersucht als eine von sehr wenigen Studien, ob ein höheres Ausmaß an Hyperaktivität diesen Zusammenhang moderiert. Die Ergebnisse zeigen, dass Jugendliche an Tagen, an denen sie körperlich aktiver sind als gewöhnlich, einen geringeren depressiven Affekt am Abend berichten als an Tagen, an denen sie körperlich weniger aktiv sind als gewöhnlich. Wie erwartet ist dieser intraindividuelle Zusammenhang größer bei Jugendlichen mit einem höheren Ausmaß an Hyperaktivität. Mit jeder zusätzlichen Einheit von 10,000 Schritten pro Tag (d.h. zusätzlich zu ihrer durchschnittlichen Schrittzahl pro Tag) ging der depressive Affekt von Jugendlichen fast gegen Null.

Manuskript III zielt auf die Untersuchung des intraindividuellen Zusammenhangs zwischen der körperlichen Alltagsaktivität (Minuten pro Tag mäßige bis starke körperliche Aktivität, erfasst durch Beschleunigungssensoren) und dem depressiven Affekt am selben Abend und am nächsten Morgen bei Jugendlichen ab und stellt somit eine Ergänzung zu Studie 1 von Manuskript II dar. Manuskript III geht jedoch über Manuskript II hinaus, vor allem im Hinblick auf die Stichprobengröße, die Erfassung der körperlichen Aktivität (Beschleunigungssensoren statt Schrittzähler) und die Häufigkeit der Erfassung des depressiven Affekts (zweimalige statt einmalige Messung pro Tag). Darüber hinaus untersucht Manuskript III, im Gegensatz zu Manuskript II, Geschlecht und Wochentag (d.h. Wochentag versus Wochenendtag) als Moderatoren des intraindividuellen Zusammenhangs. Die Ergebnisse weisen darauf hin, dass bei weiblichen Jugendlichen an Wochentagen eine Steigerung von 60 Minuten mäßiger bis starker körperlicher Aktivität zusätzlich über das gewohnte Ausmaß hinaus (d.h. den Personen-Mittelwert) eine Reduktion des depressiven Affekts um 50% am nächsten Morgen vorhersagt. Einen entsprechenden zeitlich-verzögerten Zusammenhang an Wochenendtagen oder bei männlichen Jugendlichen wurde nicht gefunden. Außerdem konnte kein intraindividueller Zusammenhang zwischen mäßiger bis starker körperlicher Aktivität und depressivem Affekt am Abend (d.h. kein Zusammenhang am selben Tag) gefunden werden.

Auf der Grundlage der Ergebnisse aus den drei Manuskripten, verdeutlicht die vorliegende Dissertation die Bedeutung (a) multiple, vielfältige Barrieren körperlicher Aktivität zu betrachten, die für Jugendliche relevant sind, sowohl für die Gesundheitsforschung als auch für die Praxis, und (b) natürlich auftretende, zeitlich-verzögerte Veränderungsprozesse sowie Veränderungsprozesse innerhalb eines Tages systematisch unter Alltagsbedingungen zu untersuchen, um die intraindividuellen Zusammenhänge zwischen körperlicher Aktivität von Jugendlichen und ihrem depressiven Affekt besser zu verstehen. Zusätzlich veranschaulichen die Ergebnisse aus den Manuskripten II und III das große Potenzial von körperlicher Alltagsaktivität bei der Verminderung des depressiven Affekts von Jugendlichen auf Tagesebene. Weitere Forschung ist jedoch notwendig, um die Ergebnisse dieser Dissertation zu replizieren.

1. General Introduction and Research Questions

In this chapter, the theoretical background including concepts and previous research central to Manuscripts I-III (physical activity, barriers to physical activity, physical activity-depressed affect link among adolescents with and without hyperactivity), providing the basis for this dissertation, will be reviewed. Finally, the resulting most important, still unanswered research questions will be summarized.

1.1 Physical Activity in Adolescents

The following four paragraphs describe definitions and concepts of physical activity, internationally accepted physical activity recommendations and epidemiological research on adolescents' physical activity, various measurement approaches, and open research questions.

1.1.1 Definition of Physical Activity

Health researchers generally define physical activity as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, Powell, & Christenson, 1985, p. 126). As a multidimensional construct physical activity is mostly described by its duration (i.e., time spent performing physical activity), frequency (i.e., number of physical activity sessions during a particular time period), and intensity (i.e., physical activity level)—with all of these dimensions being important contributors to physical and mental health benefits that likely result from physical activity (Strath et al., 2013). The type of physical activity (indoors versus outdoors; individual- versus team-oriented; cooperative versus competitive), another important physical activity dimension, defines the context of "how," "where," and "with whom" physical activity is performed (Burton, Khan, & Brown, 2012).

Despite the commonly accepted definition of physical activity, the terms "physical activity", "exercise", and "sports" are commonly used interchangeably. However, these terms are not synonyms and are generally distinguished from sedentary behavior. In contrast to physical activity, *exercise* is usually conceptualized as "a subset of physical activity that is planned, structured, and repetitive" (Caspersen et al., 1985, p. 126) such as jogging, swimming, cycling, and gymnastics. Through exercise individuals usually attempt to maintain or improve varying components of physical fitness. *Physical fitness*, in turn, relates to the ability to perform physical activity and can be divided into health-related and skill-related components. Health-related components include cardiorespiratory endurance, muscular endurance, muscular strength, body composition (e.g., relative amounts of muscles, bones, and fat), and flexibility (range of motion); skill-related components comprise agility (i.e., ability to change one's body position in space with speed and accuracy), balance, coordination (i.e., ability to use one's senses together with specific body parts to perform tasks smoothly and accurately), speed, power, and reaction time (Caspersen et al., 1985). Although the terms "exercise" and "sports" are frequently confused, there are major differences between them. As opposed to exercise, *sports* are typically subdivided into either leisure or competitive individual sports (e.g., golf, squash, and judo) or team sports (e.g., basketball, hockey, and soccer), and are characterized by a set of predetermined rules, and definable outcomes (World Health Organization, WHO, 2010). In addition to exercise and sports, physical activity also includes active transportation (e.g., walking, climbing stairs, and cycling), physical education, household chores, gardening, and other outdoor pursuits. *Sedentary behavior,* by contrast, relates to "activities that do not increase energy expenditure substantially above the resting level" (Pate, O'Neill, & Lobelo, 2008, p. 174) such as sitting and lying down while watching TV, playing computer games, or browsing and chatting. Sedentary behavior should not be confused with the absence of physical activity. Since sedentary behavior and physical activity predict the risk for chronic diseases and mortality independently (Ortega et al., 2013) they should be regarded as distinct constructs and should, therefore, be measured separately (Pate et al., 2008).

With regard to physical activity, health researchers are particularly interested in the level of intensity, because specific intensity levels are supposed to be associated with specific health benefits. Quantifying the intensity of physical activity is, however, much more complicated than assessing the duration (time spent with physical activity) and frequency of physical activity (number of physical activity sessions performed) (Pescatello, Arena, Riebe, & Thompson, 2014). In general, two ways of determining the intensity of physical activity can be distinguished: (a) relative intensity (i.e., an individual's level of effort in relation to his or her level of cardiorespiratory fitness; indicated by heart rate, heart rate reserve, oxygen consumption, and oxygen uptake reserve) and (b) absolute intensity (based on an individual's energy expenditure during physical activity, without taking into account his or her level of cardiorespiratory fitness; indicated by metabolic equivalent, MET). This dissertation focuses on the absolute intensity of physical activity which is commonly divided into the following three levels (Ainsworth et al., 2011): light (1.6 to 2.9 METs), moderate (3.0 to 5.9 METs), and vigorous (6.0 or more METs; see Ridley, Ainsworth, & Olds, 2008, for more details and examples of physical activities performed by adolescents and related METs). Most frequently, researchers study moderate-to-vigorous physical activity (hereafter referred to as MVPA) which can be described as the total time spent with moderate and vigorous physical activity, respectively, during a particular time period. A MET, a widely used and standardized parameter to describe an individual's energy expenditure during physical activity, is determined by the ratio of energy expenditure during physical activity (work metabolic rate) to the energy expenditure while the body is at rest (basal or resting metabolic rate). By convention, 1 MET is the energy expenditure while resting quietly (i.e., resting energy expenditure; also called basal metabolic rate) and corresponds to an oxygen uptake of 3.5 ml per kg of body weight per minute (WHO, 2010). For example, an activity with a MET value of 6 expends 6 times the energy used by the body at rest (U.S. Department of Health and Human Services, 2008). MET values of physical activity can range between 0.9 METs (sleeping) and 23.0 METs (running at 22.5 km/h), with sedentary behavior ranging from 1.0 to 1.5 METs (Ainsworth et al., 2011).

1.1.2 Physical Activity Recommendations and Epidemiology

Several organizations and agencies (e.g., WHO, Centers for Disease Control and Prevention of the U.S. Department of Health and Human Services) have made recommendations for adolescents' physical activity participation. The WHO, for example, recommends that healthy adolescents (up to 17 years of age) perform at least 60 minutes per day of MVPA either in multiple bouts or episodes of at least a 10-minute duration throughout the day to improve their physical and mental health (WHO, 2010). As part of their 60 minutes of daily physical activity, adolescents should perform vigorous physical activity, including those activities that strengthen their muscles (e.g., weightlifting, doing push-ups, and climbing) and bones (e.g., brisk walking or running, jumping, playing basketball or tennis), on at least three days per week. Most daily physical activity should be performed on a moderate intensity level over longer time periods to increase adolescents' endurance. This type of physical activity, also called aerobic physical activity (e.g., swimming, jogging, rowing, and bicycling), is known to improve adolescents' cardiorespiratory fitness (WHO, 2010). By contrast, anaerobic physical activity (e.g., weightlifting and sprinting) improves adolescents' muscular strength and is characterized by brief bouts of vigorous physical activity that usually cannot be sustained for long (WHO, 2010). This dissertation focusses on aerobic physical activity (hereafter referred to as physical activity). According to the American College of Sports Medicine (Pescatello et al., 2014), previously sedentary or overweight adolescents, however, should depart from the above mentioned recommendations. Instead, they should start out with shorter durations, lower frequencies, and lower intensity levels, and gradually increase their physical activity level until they are able to participate in at least 60 minutes per day of MVPA. Adolescents with a chronic health condition such as asthma or diabetes mellitus should adapt the amount of physical activity to the severity of their symptoms and physical fitness (Pescatello et al., 2014).

For healthy adults (18 years and older), the WHO, for example, recommends at least 150 minutes per week of moderate physical activity or at least 75 minutes per week of vigorous physical activity, or an equivalent combination of moderate and vigorous physical activity, performed in multiple bouts of at least a 10-minute duration throughout the week, in order to gain health benefits (WHO, 2010). When aiming for additional health benefits, adults have to double their weekly amount of moderate or vigorous physical activity, or an equivalent combination of moderate and vigorous physical activity (i.e., at least 300 or 150 minutes per week of moderate or vigorous physical activity). Muscle-strengthening (i.e., anaerobic) physical activity, involving major muscle groups, should be performed on at least two days of the week.

During the transition from childhood to adolescence, MVPA decreases by approximately 40 minutes per day each year (e.g., Nader, Bradley, McRitchie, Houts, & O'Brien, 2008). Today, worldwide, 80-90% of adolescents do not reach public health guidelines for recommended levels of daily physical activity (e.g., Hallal et al., 2012; Jekauc, Reimers, Wagner, & Woll, 2012; Troiano et al., 2008), with young women showing an even sharper decrease in MVPA than young men (e.g., Dumith, Gigante, Domingues, & Kohl, 2011; Hallal et al., 2012; Nader et al., 2008). In addition, on weekend days, young women and men generally perform less MVPA compared to weekdays, maybe due to different weekend priorities or fewer opportunities for physical activity participation (Comte et al., 2013; Corder et al., 2014; Nader et al., 2008; Ortega et al., 2013). So far, little is known about the potential reasons for this substantial decrease in MVPA with age, which also seems to continue through adulthood (Troiano et al., 2008) and to result in serious short- and long-term physical and mental health problems among adolescents (with respect to the cardiorespiratory system, insulin sensitivity, lipid profile, muscle strength, bone strength, affect, and self-esteem; Duckham et al., 2014; Ekelund et al., 2012; Janz et al., 2014). Some researchers have argued that this decline may be due to a smaller variety (i.e., number of different types) of activities rather than less time spent in each activity (Aaron, Storti, Robertson, Kriska, & LaPorte, 2002). Dumith and colleagues (2012) and Kjønniksen, Torsheim, and Wold (2008) showed that the variety of activities during childhood and early adolescence seems to predict the amount of physical activity performed in mid adolescence and young adulthood, respectively.

The next subchapter will address the complexity of physical activity and its assessment in the light of reliability, validity, and responsiveness (i.e., sensitivity) to change (Warren et al., 2010).

1.1.3 Measurement of Physical Activity

To accurately measure physical activity is essential for studying current levels and changes of physical activity including prevalence, correlates and determinants of physical activity (Bauman et al., 2012), effects of physical activity interventions, and dose–response relationships between physical activity and health outcomes such as depressed affect (Atienza et al., 2011; Warren et al., 2010). As a multidimensional and complex behavior to measure, physical activity should be assessed through various methods to capture as many dimensions as possible (i.e., duration, frequency, intensity, and type of physical activity) that may vary on a day-to-day basis (Armstrong & Welsman, 2006; Warren et al., 2010). Physical activity researchers generally distinguish indirect measures (self-reports such as questionnaires and activity logs (i.e., diaries) from direct measures[1] (heart rate monitors, motion sensors such as pedometers and accelerometers, and direct observation). These methods vary with respect to outcomes, feasibility, objectivity, reliability, validity, and responsiveness (i.e., sensitivity to detect change over time).

Among the *indirect measures*, *self-reports* are the most widely used method to assess physical activity, particularly in studies with large sample sizes, due to high practicability, low costs, and low participant burden (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009). Self-reports are comprised of questionnaires (weekly, monthly, yearly, general amount of physical activity) and/or diaries (e.g., daily amount and types of physical activity). Which type of self-reports researchers select depends on the respective research question as well as participants' age. By using self-reports, researchers study (a) the number of physical activity bouts and (b) the time spent in various types or domains of activities (i.e., household, occupational, transportation, and leisure time domains) at various intensity levels, and (c) the estimated energy expenditure. Researchers attempt to estimate energy expenditure by translating the amount of physical activity reported by adolescents within a specified timeframe (duration) into MET values, based on comprehensive coding schemes for assessing physical activity intensity levels (Ainsworth et al., 2011). However, the reliability and validity of self-reports for estimating energy expenditure is usually poor (Corder, Ekelund, Steele, Wareham, & Brage, 2008). However, when using self-reports researchers can rank participants according to their physical activity and can estimate group-level physical activity with reasonable

[1] The term "objective" measures, commonly used to describe motion sensors, seems to some extent misleading, since different accelerometers, for example, use different, mostly unknown algorithms to convert activity counts or raw acceleration data into physical activity units (i.e., to quantify the intensity of physical activity performed). Moreover, a complete standardization of measuring physical activity by using accelerometers has not been realized yet (Bassett, Troiano, McClain, & Wolff, 2015). Therefore, the term "direct" instead of "objective" measures appears much more suitable.

accuracy (Corder et al., 2009; Warren et al., 2010). The two most important criteria for selecting an appropriate self-report measure are reliability and validity (Warren et al., 2010). In general, self-reports have two key limitations: they are known to be susceptible to (a) response bias (i.e., overestimation of physical activity, underestimation of sedentary behavior—possibly due to social desirability) and (b) recall bias (due to high cognitive demands of recalling planned as well as sporadic physical activity bouts and frequently changing intensities, particularly for children and younger adolescents; Adamo et al., 2009).

There is plenty of evidence that most physical activity *questionnaires* are less reliable and valid than direct physical activity measures such as accelerometers (Sirard & Pate, 2001). Despite these methodological restrictions, physical activity questionnaires have also many advantages which have been addressed above. Currently, more than 60 physical activity questionnaires for adolescents (Chinapaw, Mokkink, van Poppel, van Mechelen, & Terwee, 2010) and more than 80 for adults (van Poppel, Chinapaw, Mokkink, van Mechelen, & Terwee, 2010) are available for selection, with some of them having been calibrated against direct physical activity measures. A recent systematic review provides guidance for researchers which particular instrument to select for the population of interest (Sternfeld & Goldman-Rosas, 2012). Within validation studies, the correlations between physical activity self-reports and accelerometers are generally higher for adolescents than children due to greater recall bias and more spontaneous or sporadic physical activity patterns in children (Ellery, Weiler, & Hazell, 2014). This diversity of physical activity questionnaires, however, makes it harder for researchers to compare physical activity data across studies and countries and to draw valid conclusions from these. The International Physical Activity Questionnaire (IPAQ; Craig et al., 2003), currently the most widely used physical activity self-report instrument (Biddle, Gorely, Pearson, & Bull, 2011; van Poppel et al., 2010), was designed to better compare various surveillance studies with participants between 15 and 65 years of age. Two versions of the IPAQ are available, the 31-item long form (IPAQ-LF) and the 9 item short form (IPAQ-SF), both assessing the time, participants spent with physical activity at varying intensity levels (sedentary, light, moderate, and vigorous) during the previous week. Since the IPAQ-SF was administered in Manuscript I of this dissertation, this version is described in greater detail below (see Guidelines for the data processing and analysis of the International Physical Activity Questionnaire (IPAQ) – short and long forms contents, 2005, for details on the long form of the IPAQ). In the IPAQ-SF, participants are asked to indicate the frequency (days per week) and duration (minutes per day) of walking, moderate- and vigorous-intensity activity as well as the duration of sitting (minutes per weekday) during the previous week. In Manuscript I, minutes per week of moderate and vigorous physical activity, MVPA, and walking were computed. Most of the IPAQ validation studies focused on adults aged 18 years and older (Craig et al., 2003; Lee, Macfarlane, Lam, & Stewart, 2011). One study (Rangul, Holmen, Kurtze, Cuypers, & Midthjell, 2008), however, investigated the reliability and validity of the IPAQ-SF among adolescents, aged 13-18 years, and showed a moderate correlation between vigorous activity and cardiorespiratory fitness (maximal oxygen consumption). Measured against a motion sensor (ActiReg; PreMed AS, Oslo, Norway; outcomes: minutes per week spent with physical activity of varying intensity levels and total energy expenditure), the validity of the IPAQ-SF was low (Rangul et al., 2008). Moreover, the reliability of the IPAQ-SF was also lower than acceptable standard—because adolescents tended to overestimate their overall amount of physical activity and were susceptible to misclassify physical activity intensity levels. Moreover, the authors assumed that physical activity, particularly that of younger adolescents, might vary considerably from week to week or even day to day (Rangul et al., 2008). Thus, the reference period of the IPAQ-SF ("during the previous week") might have an adverse impact on the instrument's test-retest reliability.

Compared with questionnaires, *diaries* are commonly used to quantify adolescents' physical activity more precisely, by referring to the last 24 hours or less (for an overview of available activity diaries see, for example, Corder et al., 2008). This method is usually more burdensome than questionnaires, since adolescents have to complete them every day, every hour, or when prompted (i.e., at random). To capture day-to-day variations of physical activity through diaries as well as possible, physical activity has to be reported in predetermined time slots that should be as short as possible (e.g., every 15 minutes). The shorter the time slots, the higher the burden, which may, in turn, have a negative impact on participants' compliance as well as physical activity. Therefore, diaries should be used only with adolescents, but not with younger children who may cope less well with this complex task. However, even a 15-minute time window may be too long to capture some short-term activities (Corder et al., 2008). When studying physical activity variations within short time windows, direct measures seem to be better suited than activity diaries. In addition, diaries can complement direct measures, especially when the type and other context factors of physical activity (e.g., time spent with water-based activities and sleeping hours) are to be studied.

Direct measures generally include wearable motion sensors (accelerometers, pedometers), heart rate monitors, doubly labelled water, calorimetry, and direct observation (Warren et al., 2010). Despite their valuable advantages due to quality criteria and diversity of outcomes (e.g., duration, frequency/number of bouts, intensity, and energy expenditure), some direct measures are rather expensive, time-consuming, and to some extent also burdensome (Trost, 2007). Direct measures are used by default to validate indirect measures such as physical activity questionnaires (Ellery et al., 2014). The appropriate direct measure depends on various factors such as sample size, duration of monitoring, and resources. Today, pedometers and accelerometers in particular are increasingly used to quantify the amount and intensity of physical activity, with accelerometers being currently the most favored devices (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013). Since both pedometers and accelerometers were used in Manuscript II and III, these devices will be described in the next paragraph in greater detail. Information on how the other direct measures (heart rate monitors, doubly labelled water, indirect calorimetry, and direct observation) work and should be used appropriately can be found elsewhere (Sirard & Pate, 2001; Trost, 2007; Warren et al., 2010).

Pedometers (i.e., step counters) are usually cheaper than accelerometers and the data can be processed and analyzed more easily than accelerometer data; for these reasons, pedometers are among the most commonly-used, reliable and valid devices to monitor the amount of adolescents' everyday physical activity (Corder et al., 2008; Tudor-Locke, McClain, Hart, Sisson, & Washington, 2009). Most pedometers, however, only store the total number of steps taken per day for the last seven days (Stryker, Duncan, Chaumeton, Duncan, & Toobert, 2007) and cannot quantify the other important dimensions of physical activity such as intensity. A systematic review showed that pedometers are a reliable and valid method for measuring physical activity (particularly walking at faster speeds) when compared with accelerometers (median correlation: $r = 0.86$; Tudor-Locke, Williams, Reis, & Pluto, 2002). Pedometer outputs depend on participants' stride length (which depends on age) and, in particular, the mechanism used (Warren et al., 2010). Generally, pedometers can be divided into mechanical (i.e., spring-levered) and piezoelectric devices (Butte, Ekelund, & Westerterp, 2012). Mechanical devices have a mechanical gear, that is, a horizontal spring-suspended lever arm that moves with the vertical acceleration while walking (Tudor-Locke et al., 2002). They must be worn vertically to count the number of times a certain acceleration threshold is exceeded. The movement (vertical acceleration) opens and closes an electrical circuit, and as the spring-suspended lever arm makes contact, the pedometer registers a step. Piezoelectric devices have a

> horizontal cantilevered beam with a weight on the end that compresses a piezoelectric crystal when subjected to elevation of the hips during walking (acceleration). This generates a voltage proportional to the acceleration. The voltage oscillations are used to record steps. (Carroll et al., 2012, p. 467)

Piezoelectric pedometers count the number of zero crossings in the acceleration waveform (i.e., step counts as a result of vertical body displacement and hip acceleration, respectively) and sum this up to give an overall estimate of steps taken. As compared to spring-levered pedometers, piezoelectric pedometers are more sensitive at slower speeds and the output does not depend on the position or tilt of the pedometer. With both devices, researchers should take into account that most pedometers display the current number of steps taken throughout the day, meaning that pedometers can also be considered as a motivational tool which enable self-monitoring (reactivity of measurement). However, administering direct measures to monitor physical activity can itself influence the amount of physical activity performed (Adamo et al., 2009). Depending on the respective research objective, this constitutes either a disadvantage (observational studies that investigate habitual physical activity as a trait) or an advantage (studies investigating physical activity change such as intervention studies or intensive longitudinal studies). However, this motivational "bias" should diminish when adolescents have become acquainted with pedometers (Newton, Wiltshire, & Elley, 2009).

Descriptive epidemiology of pedometer-based physical activity varies due to socio-demographic characteristics such as age and gender. Current research indicates that during childhood, boys and girls walk on average 12,000-16,000 and 10,000-13,000 steps per day, respectively (Tudor-Locke et al., 2011). At the age between 13 (for girls) and 14 (for boys) steps counts climax (Hands, Parker, Glasson, Brinkman, & Read, 2004). From then on, with each year, the number of steps per day decreases, with adolescents being 18 years walking only 4,500-6,000 (young women) and 8,500-10,000 steps per day (young men), respectively (Craig, Cameron, & Tudor-Locke, 2013). In general, within-person mean steps per day are higher in boys or young men than girls or young women. Cut points (i.e., step thresholds) for adolescents equal those of adults (10,000-step threshold; Tudor-Locke & Bassett, 2004) and range between 10,000 and 11,700 steps per day which corresponds to the recommended 60 minutes of MVPA per day (Tudor-Locke et al., 2011).

In the study described in Manuscript II, a commercially available, waist-worn piezoelectric pedometer (OMRON Walking Style II (HJ-113); OMRON Healthcare, Mannheim, Germany) was given to adolescents. The HJ-113 uses a biaxial acceleration sensor, placed horizontally or vertically, to count adolescents' steps accurately at all speeds (Giannakidou et al., 2012). The exact procedure of administering the HJ-113 and analyzing the pedometer output (i.e., steps per day) is described in Manuscript II. Like all other measures of physical activity, pedometers also have particular disadvantages due to the outcome measure (i.e., only steps taken per day) and data processing. Particularly in regard to varying exclusion levels (e.g., required number of valid wear days) comparability across studies is reduced. Due to varying approaches for analyzing pedometer data (e.g., average number of steps taken) combined with the tendency to treat partial data sets (e.g., 4 out of 7 monitoring days) the same as complete ones (e.g., 7 out of 7 monitoring days), comparability and statistical power are diminished.

Over the last 20 years, the use of *accelerometry* has increased rapidly (Bassett et al., 2015; see Troiano, McClain, Brychta, & Chen, 2014, for a review of the history of accelerometer use in physical activity research). Currently, accelerometers are considered the most commonly used direct measures in physical activity research across all age groups (Cain et al., 2013). Accelerometers are generally used to measure habitual, "real time" physical activity over several consecutive weekdays and weekend days to quantify variations of various physical activity intensity levels (Corder et al., 2008; De Vries et al., 2009). In addition, accelerometers are applicable to various study designs, such as cross-sectional, (intensive) longitudinal, and intervention studies, as well as dose-response studies. To estimate physical activity intensity levels over time, accelerometers measure body acceleration at a fixed body location (usually the waist; Bassett et al., 2015). Body acceleration is defined as the change in speed with respect to time (speed, in turn, is the change in position with respect to time) and is quantified in gravitational acceleration units (g; $1\ g = 9.8\ m \cdot s^{-2}$) (see McClain& Bassett, 2005; Pober, Staudenmayer, Raphael, & Freedson, 2006; Troiano et al., 2014, for a detailed overview of physical processes). An individual's body acceleration can be assessed in one to three orthogonal planes: (a) vertically (uni-axial sensors; most commonly used, however, older devices), (b) vertically and medio-laterally (bi-axial sensors), or (c) vertically, medio-laterally, and anterior-posterior (tri-axial sensors; newer devices) (Chen & Bassett, 2005). Whereas some, particularly older generations of devices can only store model- and brand-specific, preprocessed so called activity counts (amplitude multiplied by frequency of vertical accelerations), others, particularly newer devices, can record the raw acceleration signal which is only converted into activity counts when data collection has been completed (Bassett et al., 2015). Activity counts are usually summed, separately for each plane, within selected time intervals (epochs). The higher the activity counts, the higher the respective physical activity intensity level. Epochs indicate the amount of time over which activity counts are recorded, integrated, and/or stored. The increasing variety of algorithms used to convert activity counts into time spent with physical activity at various intensity levels limits the comparability across studies (Bassett et al., 2015). Since older devices have less memory capacity than newer devices, a 60-second epoch has been the most commonly used epoch; however, by selecting shorter epochs (between 1- and 30-second epochs), sporadic, short bursts of physical activity are monitored more precisely (Cain et al., 2013). Besides activity counts and epochs, cut-points are needed to classify physical activity intensity levels; by using cut-points (expressed as counts per min, cpm), researchers estimate the time adolescents spent with physical activity at various intensity levels (Bassett et al., 2015). Selecting appropriate cut-points for the population under study appears essential for estimating physical activity intensity levels accurately as cut-points vary according to age (Bassett et al., 2015; Bonomi, Goris, Yin, & Westerterp, 2009). Thus, they usually have a high impact on the respective physical activity outcome (McClain, Abraham, Brusseau, & Tudor-Locke, 2008). Another important variable is participants' amount of time of not wearing the accelerometer (so called non-wear time per day), particularly for (a) studying participants' compliance, (b) assessing whether the measurement can be considered reliable, and (c) for data cleaning purposes. Non-wear time per day is usually calculated by summing all consecutive zero cpm – allowing for a small number of non-zero interruptions. Hence, wear time is the total possible time minus participants' non-wear time (Cain et al., 2013). Non-wear time usually ranges between 10 and 180 minutes of consecutive zero counts; 10- and 20-minute units of consecutive zeros are the two most common standards. Moreover, when using accelerometers researchers have also to state the number of wearing hours per day that constitute a valid wear day. In studies with adolescent, the range of valid hours per day typically range between 8 and 12 hours, with 8 and 10 valid hours being most commonly applied. In addition, 3 to 4 valid wear days including at least 1 weekend day, are typically used (Cain et al., 2013).

Since the ActiGraph GT3X+ (ActiGraph, LLC, Pensacola, FL) was administered to adolescents in Manuscript III, this device will be the subject of the following paragraph. Besides ActiGraph accelerometers, there are also other models and brands (e.g., Actical, RT3; see John & Freedson, 2012; Rothney, Schaefer, Neumann, Choi, & Chen, 2008; Rowlands, Thomas, Eston, & Topping, 2004, for more details on the RT3) that have been used in physical activity research with adolescents. However, ActiGraph accelerometers are considered the most commonly used accelerometers worldwide. The GT3X+, a piezoelectric sensor-based monitor (John & Freedson, 2012), belongs to the newer generation of tri-axial ActiGraph accelerometers and has been tested in various settings (laboratory and free-living environments) and with various populations (children, adolescents, and adults) (Cain et al., 2013). However, only recently have ActiGraph vector magnitude cut-points (acceleration data of all 3 axes are combined to a single value) been available to classify physical activity intensity, but only for adults (Sasaki, John, & Freedson, 2011) and preschoolers (Butte et al., 2014). Thus, when using ActiGraph accelerometers, analyzing only the acceleration of the vertical axis is currently still the standard of data processing (Bassett et al., 2015) as was the case with Manuscript III. In adolescents, the GT3X+ has been proved to be reliable and valid (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Freedson, Pober, & Janz, 2005; Puyau, Adolph, Vohra, & Butte, 2002). Responsiveness of accelerometers is another important feature, besides reliability and validity, because even slight increases in physical activity can provide physical and mental health benefits for adolescents (Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009). This is particularly the case with studies applying an intensive longitudinal approach as was the case with Manuscript III. According to Montoye, Pfeiffer, Suton, and Trost (2014), the GT3X+ is highly responsive to small changes of adolescents' everyday physical activity, regardless of the selected cut-points and epoch lengths. In the study described in Manuscript III, the sampling rate was set to 60 Hz; the raw acceleration signal of the vertical plane was downloaded and aggregated into 15-s epochs by using ActiLife 5 by ActiGraph (Pensacola, FL, US), and scanned for spurious data and processed by using KineSoft (version 3.3.67, Saskatchewan, Canada). Non-wear time was determined as 60 minutes of consecutive zeros of activity counts allowing for two minutes of non-zero interruptions (Troiano et al., 2008). Days with wear times of 600 minutes or more were considered valid days (Colley, Gorber, & Tremblay, 2010). Well-established standard cut-points for adolescents (Troiano et al., 2008) were used to quantify minutes per day adolescents spent with physical activity at various intensity levels: sedentary (< 100 cpm), light (≥ 100 < 2020 cpm), and moderate (≥ 2020 < 6000 cpm), vigorous (≥ 6000 cpm), and moderate-to-vigorous (≥ 2020 cpm). Since current physical activity guidelines focus exclusively on the time spent with MVPA, this was the main outcome variable of Manuscript III.

Although accelerometers have become the gold standard for measuring adolescents' everyday physical activity (Cain et al., 2013), due to their many advantages over other assessment approaches such as questionnaires (Welk, 2002), they are not without limitations: First, accelerometers cannot measure all bodily movements equally. For example, waist-worn accelerometers (typical placement position) measure locomotor activity and, thus, do not capture upper body movements or cycling (Warren et al., 2010). Moreover, since most accelerometers are not waterproof, water-based activities cannot be monitored. Second, when acceleration equals zero, a person's body may still be moving, albeit at a constant speed. In addition, accelerometers usually cannot detect a person's body position and posture, since they can only quantify dynamic but not static accelerations, implying that they cannot distinguish between sitting and standing still, for example (Warren et al., 2010). However, for most populations, this is not a major limitation. Third, since the acceleration does usually not change while walking on an incline or carrying heavy loads while walking, accelerometers usually underestimate the energy expenditure, even though a person uses more energy due to the greater effort he or she has to make.

Taken together, compared to questionnaires, accelerometers provide more valid data on adolescents' duration, frequency, and intensity of physical activity (Cain et al., 2013). However, as opposed to motion sensors, questionnaires are clearly better suited for assessing context factors of physical activity such as location, social support, and motives for engaging in physical activity (Cain et al., 2013). Moreover, questionnaires provide the opportunity to assess those physical activity types that direct measures cannot capture such as muscles- and bone-strengthening and flexibility-enhancing physical activity as well as water-based activities (Bassett et al., 2015). Therefore, it seems advisable to apply a multimethod approach whenever possible by combining various measures of physical activity to cope with the complexity of physical activity.

1.1.4 Open Research Questions with Respect to Physical Activity

With respect to physical activity, the following open research questions focus on (a) measuring methods of physical activity (i.e., direct versus indirect measures), (b) the feasibility of accelerometry when studying adolescents, (c) the investigation of stable factors that may influence physical activity, and (d) the dose-response relationship between adolescents' physical activity and mental health outcomes such as depressed affect.

For decades, physical activity has been assessed almost exclusively through physical activity questionnaires due to high availability and practicability, low costs, and low participant burden (Adamo et al., 2009). As technology has progressed, measuring physical activity with direct measures, such as accelerometers, has become more and more popular (Cain et al., 2013). So far, the feasibility of assessing physical activity using accelerometers has been studied occasionally and only in homogeneous samples, particularly among toddlers (e.g., Van Cauwenberghe, Gubbels, De Bourdeaudhuij, & Cardon, 2011), preschoolers and children (e.g., Mattocks et al., 2008), and older adults (e.g., Murphy, 2009). Studies that test the feasibility of accelerometry among adolescents at varying ages and with different socioeconomic and educational backgrounds are largely lacking. Studying feasibility is important to increase acceptability of and compliance with the use of accelerometers in adolescents. Therefore, research should thoroughly investigate the overall number of valid wear days, daily wear time on weekdays and weekend days, drop-outs, as well as the association with sociodemographic variables. Manuscript III of this dissertation takes a closer look at this important issue. Moreover, more studies are needed that examine direct measures as the method of choice to gain a deeper insight into which physical activity components (duration, frequency, intensity, and perhaps type as far as possible) are crucial for improving adolescents' mental health. In the majority of accelerometer studies, physical activity has been assessed as the only time-varying variable. Research that focuses on the association (i.e., within-person link) between physical activity and other time-varying variables—particularly, depressed affect— within person is rare (Biddle & Asare, 2011; Hume et al., 2011). Manuscript II and III of this dissertation address this research question by applying an intensive longitudinal approach. Both manuscripts also consider the question of whether stable variables such as gender and/or hyperactivity (treated as a trait) might be possible moderators of this within-person link. Studying the dose-response relationship between physical activity and depressed affect, especially among adolescents, appears as another worthwhile, yet understudied research objective. Manuscript II and III examine the additional amount of physical activity that adolescents have to perform (additional steps taken per day or additional minutes per day of MVPA) to gain a significant decrease of depressed affect. The stronger the evidence that more physical activity at particular intensity levels leads to better mental health outcomes, the more likely physical activity will be regarded as another important treatment complementary to or even instead of medication. In addition, as opposed to antidepressants, for example, a prescription of physical activity by physicians considerably reduces the costs to the health care system and has significantly fewer and less serious side effects when used in accordance with internationally accepted physical activity guidelines (WHO, 2010). A prescription of regular physical activity might be a strong signal particularly to less physically active adolescents, that they must become more physically active if they do not want to fall ill. However, a prescription of physical activity alone will not ensure that these adolescents will get started (Hallal & Lee, 2013), especially when they experience several barriers to physical activity, which are important correlates of physical activity that will be addressed in the subsequent section.

1.2 Barriers to Physical Activity in Adolescents

Starting with an overview of the variety of definitions of barriers to physical activity, this subchapter will describe frameworks for embedding barriers to physical activity theoretically as well as practically with diverse measurement approaches. Then, previous studies focusing on the impact of barriers on adolescents' physical activity will be reviewed and open research questions will be summarized.

1.2.1 Definition of Barriers to Physical Activity

As described in the last subchapter on physical activity, the majority of adolescents—not only in Germany but in many Western countries—do not meet the internationally accepted MVPA guidelines. For this reason, researchers have investigated the factors which might be associated with adolescents' MVPA participation. Besides other psychosocial correlates of physical activity, such as self-esteem or social support, researchers have particularly focused on the barriers to physical activity adolescents might have to struggle with in the course of initiation, maintenance, and resumption of physical activity. In this context, Bandura (1995) stated that behavioral change "would be trivially easy if there were no impediments or barriers to surmount" (p. 3). Other authors have gone as far as to view barriers as causes for non-participation in physical activity (e.g., Dishman, 1988; Godin et al., 1994; Sallis et al., 1989). Definitions of barriers vary considerably across the theories of health behavior change (Brawley, Martin, & Gyurcsik, 1998). Jackson (1988) suggested using the term *constraints* instead of *barriers*, since *constraints* would capture a wider range of explanations for physical activity non-participation. However, over time, the term *barriers* has prevailed. Jackson (1988) described barriers to physical activity as constraints (i.e., potential correlates, not determinants) that can prevent and hamper a person from engaging in physical activity. He distinguished various categories of barriers, such as internal and external, intrapersonal (one's own preferences) and interpersonal (social interaction or participation), antecedent and intervening, as well as permanent and contemporary barriers.

Barriers to physical activity are frequently confused with negative outcome expectations (i.e., anticipated, potential negative consequences of physical activity), which constitute another important predictor of a person's health behavior. As stated by Krämer and Fuchs (2010), barriers to physical activity and negative outcome expectations seem to be distinct psychosocial constructs, since they vary in structure, content, and phase specificity (pre- versus postintentional). Negative outcome expectations are characterized by an if-then format (e.g., "If I am physically active, I will get laughed at"). They are mostly understood as pre-intentional, motivational processes (i.e., before an intention is formed), whereas barriers to physical activity are generally conceptualized as post-intentional, volitional processes (i.e., an intention is translated into a health behavior) (Krämer, 2014; Krämer & Fuchs, 2010). As summarized by Pate, Saunders, O'Neill, and Dowda (2011), the most commonly studied barriers to adolescents' physical activity are lack of motivation, competing interests, lack of skills, poor health, meetings with peers, school workload, high costs, and long distances to facilities.

Barriers to physical activity are not the same for all people but differ, for example, between young, middle-aged, and older people (e.g., due to varying developmental tasks, priorities, and health conditions), men and women (e.g., due to pregnancy, early child rearing), people with varying physical conditions (e.g., presence or absence of physical restrictions and transportation difficulties), and people from various countries with different environmental conditions (e.g., availability of convenient and safe places) or from different socioeconomic backgrounds (e.g., accessibility to sports clubs or recreational programs) (Pate et al., 2011). Gaining deeper insight into the nature and the many facets of adolescents' barriers to physical activity is an important prerequisite for developing targeted, individually tailored interventions (e.g., specific barrier management strategies and coping plans) to enable adolescents to improve their physical activity participation.

1.2.2 Theories Embedding Barriers to Physical Activity

This subchapter focuses on (a) how barriers to physical activity are embedded within theories of health behavior change (namely the Health Belief Model (HBM), the Theory of Planned Behavior (TPB), the Social Cognitive Theory (SCT), the Transtheoretical Model of Change (TTM), and the Health Action Process Approach (HAPA)) and (b) how they are commonly conceptualized (i.e., whether they are conceptualized as single, dual, or multiple barrier dimensions).

Most health researchers have recognized the importance of barriers to physical activity for health behavior change. In the HBM (Janz & Becker, 1984), barriers are conceptualized as negative outcome expectations. In the TPB (Ajzen, 1985) and the TTM (Prochaska et al., 1994), barriers are considered as part of perceived behavioral control (i.e., control beliefs about factors that might facilitate or impede a particular health behavior). In the SCT (Bandura, 1995, 2004), barriers are closely associated with self-efficacy (i.e., beliefs about one's capability to perform a particular health behavior despite the presence of barriers). Bandura (2006) emphasized that the concept of self-efficacy requires the presence of barriers because without barriers, everyone would be self-efficacious. In the SCT, Bandura (2006) views barriers as obstacles individuals have to overcome to perform a particular health behavior, such as physical activity, and distinguishes various barrier categories (e.g., personal, social, environmental, and structural barriers). In Manuscript I of this dissertation, barriers to physical activity are embedded within the current version of the HAPA (Schwarzer, 2008). In the original version of the HAPA (Schwarzer, 1992), barriers were conceptualized as part of the environment (e.g., lack of social support) and were viewed as post-intentional, volitional constructs. Since then, barriers have always been essential in the HAPA model. In the most current version of the HAPA (Schwarzer, 2008; Schwarzer, Lippke, & Luszczynska, 2011), barriers are exclusively associated with (action, coping, and barrier) self-efficacy—consistent with Bandura (2006)—and are not conceptualized as a discrete construct. Following the HAPA (Schwarzer, 1992, 2008; Schwarzer et al. 2011), in Manuscript I, barriers to physical activity are understood as a post-intentional construct that relates to barrier self-efficacy and occurs in the volitional phase.

All these theories of health behavior change neither specify how barriers to physical activity should be best measured nor do they question their dimensionality. Instead they rather imply that barriers are a homogenous construct. Social ecological models, based on the framework originally proposed by McLeroy, Bibeau, Steckler, and Glanz (1988), however, emphasize that barriers to physical activity have a complex, non-hierarchical structure, comprising multiple discrete dimensions that are assumed to interact. Within social ecological models, barriers can be categorized as one of six types: intraindividual barriers (individual characteristics such as attitude); situational/external barriers, including interpersonal (social networks and support systems such as a lack of physically active friends); institutional (organizational characteristics such as physical education that has been cancelled); community (occurring between organizations and institutions such as lack of community-based activities); public policy-related (local, state, and national laws and policies such as a law prohibiting of playing soccer on green spaces); and environmental barriers (actual physical context such as sidewalks or cycling trails; e.g., Green, Richard, & Potvin, 1996; Richard, Potvin, Kishchuk, Prlic, & Green, 1996; Sallis et al., 2006; Sallis, Owen, & Fisher, 2008;). Thus, social ecological models emphasize the multidimensionality of barriers to physical activity. How researchers have met the challenge of measuring barriers to physical activity, so far, will be the subject of the next section.

1.2.3 Measurement of Barriers to Physical Activity

More than two decades ago, Godin and colleagues (1994) pointed out that the method of measuring barriers to physical activity has been anything but consistent across studies. The diversity of measuring barriers to physical activity can be attributed to at least four issues: (a) missing or poor definition of barriers and absence of discrimination between barriers and other psychosocial correlates as well as "excuses", (b) lack of embedding barriers to physical activity within a theory, (c) varying methods to identify salient barriers in the target population, (d) various approaches to quantify the potential impact of barriers on physical activity, and (e) varying attempts to categorize types of barriers (i.e., dimensions) by applying either a very broad (general barriers; internal/external barriers) or a very narrow approach (each item represents a distinct barrier category). Each issue will be addressed in the following.

In most studies on barriers to physical activity, researchers fail to explicitly specify what they consider to be a barrier (Brawley et al., 1998). Another issue is that some researchers commonly use barriers to physical activity interchangeably with other related psychosocial correlates such as negative outcome expectations (Krämer & Fuchs, 2010). Although most psychosocial correlates are assumed to interact, Krämer and Fuchs (2010) indicate that health researchers should carefully distinguish between them. In this context, when studying barriers to physical activity, Jackson (1988) recommended additionally assessing an individual's intention to become physically active, which represents another important psychosocial correlate and predictor of physical activity (Bauman et al., 2012). Otherwise, researchers do not assess barriers but rather excuses (Jackson, 1988). In line with Jackson (1988), Brawley and colleagues (1998) suggested that researchers should distinguish very carefully between actual barriers and excuses. For example, lack of time—one of the most reported barriers to physical activity—appears too unspecific to decide whether it is (a) an actually experienced barrier (e.g., due to poor time-management skills), (b) a socially acceptable excuse for laziness (possibly due to low intention), or (c) a different wording for "I prefer to do other things" (i.e., low intention). Assessing an individual's intention to be physically active should improve a measure's predictive validity.

As Godin and colleagues (1994) pointed out, barriers to physical activity should always be embedded within a theory of health behavior change such as TPB (as part of perceived behavioral control, Ajzen, 1985) or SCT (as part of self-efficacy, Bandura, 2004; McAuley, 1994). Brawley and colleagues (1998) considered that embedding barriers theoretically is essential; however, they argue that a theory-based concept can only be as good as its measurement and interpretation. Hence, measuring barriers to physical activity that are most salient to the target group (in this dissertation, adolescents) and embedding them within a comprehensive theoretical framework, enable a theoretically well-grounded explanation (in this dissertation, HAPA) for why these barriers may impact adolescents' physical activity (Brawley et al., 1998).

Over the last few decades, researchers have attempted to assess adolescents' most salient barriers by using various methods. The two most commonly applied approaches are asking adolescents to (a) self-generate barriers by using open-ended questionnaires or interviews including focus groups (e.g., Allison et al., 2005; Gyurcsik et al., 2006; O'Dea, 2003), or (b) to complete researcher-generated scales that usually contain barrier items that have been originally developed for adults (e.g., Allison, Dwyer, & Makin, 1999; De Bourdeaudhuij & Sallis, 2002).

Both approaches have advantages and disadvantages. When assessing barriers through an open-ended format, it can be assumed that adolescents report in particular those barriers that are salient to them. However, results across studies using an open-ended format cannot be compared that easily and may not represent the entire spectrum of all barriers salient to adolescents. Providing a researcher-generated list of barrier items can improve the comparability across studies, but this bears the risk that precisely those barriers may be missing that are (a) most important to adolescents and (b) most central with regard to adolescents' specific developmental tasks. So far, studies that attempt to validate questionnaires to measure adolescent-generated barriers to physical activity are still lacking.

Moreover, researchers vary considerably in how they quantify barriers and their influence on physical activity. Most commonly, barriers are quantified through (a) the number of barriers (degree of agreement that barriers actually exist), (b) the frequency with which barriers occurs, or (c) the extent of limitation (degree of agreement about the extent to which barriers hamper/prevent physical activity; difficulty of performing physical activity when faced with barriers; percentage of limitation; likelihood that barriers will prevent/hamper physical activity; degree of concern about potential barriers).

To categorize barriers, previous studies have either used a narrow or a very broad approach (Figure 1). With the narrow approach, barriers are not classified into higher-order categories. On the contrary, each barrier item represents its own barrier category (e.g., Tergerson & King, 2002). Researchers applying the broad approach either treat all barriers as equal (Garcia et al., 1995; Wu, Pender, & Noureddine, 2003; Zakarian, Hovell, Hofstetter, Sallis, & Keating, 1994) by computing an average barrier score (general/uni-dimensional factor model) or distinguish between two categories, that is, internal (i.e., individual) and external (i.e., environmental) barriers (internal-external/two-dimensional factor model) (Allison et al., 1999). More recently, theoretical models with multiple barrier dimensions have received empirical support. De Bourdeaudhuij and Sallis (2002), for example, investigated the underlying structure of barriers to physical activity by conducting exploratory factor analysis resulting in five dimensions (psychological and health barriers, lack of time, lack of interest, external obstacles, and embarrassment). Currently, social ecological models (McLeroy et al., 1988; Sallis et al., 2008) with multiple, interacting dimensions are becoming more and more important to study barriers to physical activity (Sherar et al., 2009). As already described in the previous subchapter, most social ecological models tend to emphasize various external barriers. In general, six interacting barrier dimensions (one internal, five external), can be distinguished: intrapersonal, interpersonal, institutional, community, public policy-related, and environmental barriers to physical activity (Gyurcsik et al., 2006). In a cross-sectional study, Gyurcsik and colleagues (2006) asked adolescents to report barriers that prevented them from physical activity during the previous six months by using a semi-structured, open-ended survey. The authors assigned all reported barriers to one of the following dimensions: intrapersonal, interpersonal, institutional, community, and environmental. Across all age groups (grades 7-12), the most frequently reported barriers, by far, were intrapersonal barriers, followed by interpersonal and institutional barriers. Community and environmental barriers were considerably less commonly reported, implying that the impact of barriers to physical activity experienced by adolescents themselves might deviate at least to some extent from theoretical considerations.

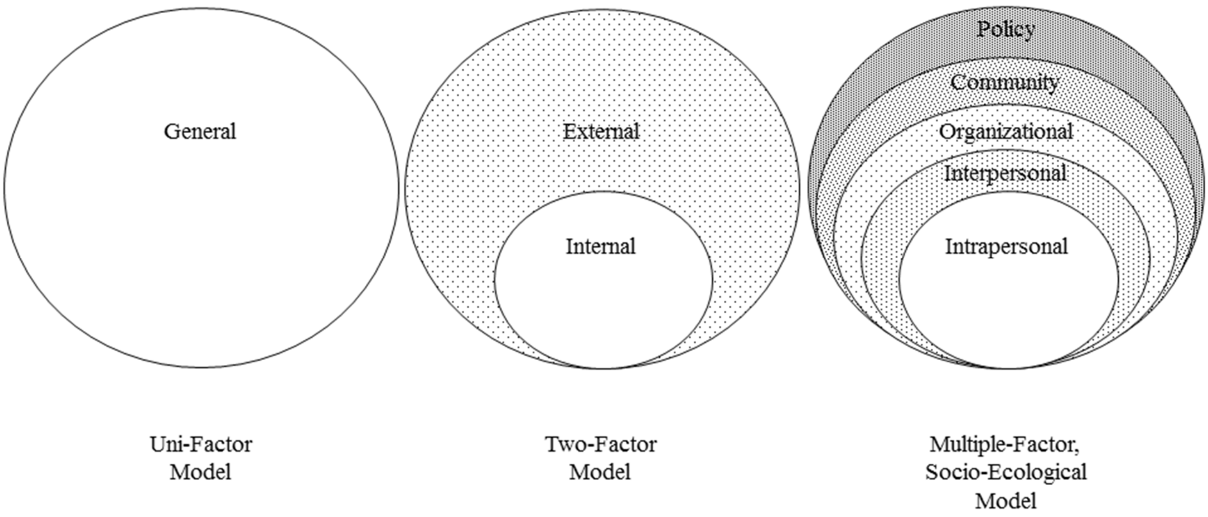

Figure 1. Approaches for categorizing barriers to physical activity.

In sum, there are various, sometimes divergent perspectives on how best to measure barriers to physical activity. Thus, before applying a particular method for assessing barriers to physical activity, researchers should consider carefully which measurement method appears most appropriate for answering their respective research question.

1.2.4 Review of the Barriers-Physical Activity Findings in Adolescents

As stated by Bauman and colleagues (2012) barriers to physical activity are an important correlate of physical activity among adults. In adolescents, however, results on the association between barriers and physical activity are rather inconsistent (Bauman et al., 2012). Overall, Bauman and colleagues (2012) reviewed three reviews on the impact of barriers on adolescents' physical activity (Biddle, Atkin, Cavill, & Foster, 2011; Sallis, Prochaska, & Taylor, 2000; Van der Horst, Paw, Twisk, & van Mechelen, 2007). Sallis and colleagues (2000) reviewed seven cross-sectional studies and one prospective longitudinal study published between 1985 and 1997 that examined adolescents aged between 13 and 18 years, with a total of 15 comparisons. Four cross-sectional studies (including five comparisons) demonstrated a negative relationship between *general barriers* and physical activity (33% of 15 comparisons were statistically significant, whereas 67% were not). On that basis, the authors concluded that, on the whole, *general barriers* did not correlate with physical activity among adolescents. Biddle and colleagues (2011) examined three cross-sectional studies (including three comparisons), published between 1999 and 2002, with a broader age range (adolescents between 10 and 18 years), which showed a small-to-moderate negative association between *general barriers* and physical activity. Van der Horst and colleagues (2007) investigated seven cross-sectional studies and one prospective longitudinal study, with a total of 13 comparisons, published between 1999 and 2004, which examined adolescents between 13 and 18 years of age. While six comparisons revealed an inverse relationship, seven did not show any relationship. The authors concluded that results on the barriers-physical activity association were inconclusive. Given that barriers are embedded in most theories of health behavior change and have been ranked among the most important correlates and predictors of physical activity across various populations, research literature on the barriers-physical activity association among adolescents seems distressingly sparse. Reviews on the relationship between barriers and physical activity among adolescents are very rare, and the existing reviews incorporated only few studies, most of them following a cross-sectional design, with some of them having missed to specify how barriers to physical activity were actually measured. In all other studies, barriers were exclusively measured in terms of *general barriers* and were not embedded within a theoretical framework. In the previous subchapter on the measurement of barriers to physical activity, this method of assessing general barriers was considered inappropriate for a number of reasons. In addition, within the reviewed studies, physical activity has usually been assessed through retrospective questionnaires with large time windows, despite the fact that these are less reliable and valid physical activity measures. However, there is at least some evidence (e.g., Biddle et al., 2011) that vigorous physical activity in particular is inversely associated with barriers to adolescents' physical activity (Allison et al., 1999; Gyurcsik, Bray, & Brittain, 2004).

Taken together, due to the very few reviews thus far, with mostly sparse data and several methodological shortcomings of the studies incorporated, it is not surprising that results on the association between barriers and physical activity in adolescents are highly inconsistent.

1.2.5 Open Research Questions with Respect to Barriers to Physical Activity

The following open research questions with respect to barriers to adolescents' physical activity refer to (a) the measurement approach (qualitative versus quantitative; scale end points), (b) the distinction between barriers and other psychosocial correlates of physical activity, (c) the saliency of barriers to physical activity to adolescents, (d) the need for theoretical embedding, and (e) the dimensional structure of barriers.

Although barriers to physical activity are considered one of the most important correlates of physical activity (Sallis et al., 2000; Van der Horst et al., 2007), results on the impact of barriers on adolescents' physical activity are highly heterogeneous (Bauman et al., 2012)—possibly due to diverse, mostly unstated definitions, conceptualizations, and measurement approaches of barriers on the one hand and diverse measurement approaches of physical activity on the other hand (Brawley et al., 1998). So far, most researchers have not mentioned how they defined and theoretically embedded barriers, and how they differentiated them from other related psychosocial correlates such as control beliefs and outcome expectations (Gyurcsik et al., 2006). Moreover, the question of whether barriers to physical activity are best measured through single, dual or multiple dimensions by applying a qualitative and/or a quantitative approach, has been so far scarcely explored (Gyurcsik et al., 2006). Consequently, most researchers have measured barriers to physical activity either only qualitatively by using focus groups or administering half-structured interviews or quantitatively through administering almost entirely researcher-generated items that usually lack those barriers that are assumed to be most salient to adolescents (Gyurcsik et al., 2006). Instead, previous quantitative studies on adolescents' barriers to physical activity have relied almost exclusively on items originally developed for adults (e.g., De Bourdeaudhuij & Sallis, 2002). Although certain barriers, such as lake of motivation, might be similar among adults and adolescents, other barriers are expected to vary due to age-specific developmental tasks (Sherar et al., 2009), such as developing close relationships to peers during adolescence versus reconciling the demands of work and family life during adulthood (e.g., Dreher & Dreher, 1985; Havighurst, 1948). When using a list of barrier items, the impact of barriers has been previously operationalized in very different ways (e.g., degree of agreement about the extent of limitation or frequency of occurrence). Moreover, sometimes barrier items represent stereotypic excuses (e.g., not having enough time), rather than actual barriers to physical activity (Brawley et al., 1998). Furthermore, when using a list of items to measure barriers to physical activity, the dimensionality and validity have most often not been tested previously. Since, as already pointed out by Brawley and colleagues (1998), there is still no generic gold standard for best measuring barriers to physical activity, future studies should consider the following key points: Researcher should (a) state clearly what they consider to be a barrier (and to distinguish barriers from other constructs); (b) embed barriers within a theoretical model of health behavior change; (c) inquire barriers to physical activity only within a predefined time interval that should be as short as possible, in order to alleviate recall bias; (d) examine only those barriers that are salient to the target population, perhaps by combining a qualitative and a quantitative approach; (e) use reasonable scale endpoints; and (f) give special consideration to the dimensionality of barriers to physical activity and to how these dimensions may interact.

1.3 Physical Activity and Depressed Affect in Adolescents

The following five paragraphs will describe definitions and conceptualizations of affect, as well as different theoretical frameworks and various measurement approaches of affect. Subsequently, previous studies investigating the impact of adolescents' physical activity on their depressed affect will be reviewed. Finally, open research questions will be outlined.

1.3.1 Definition of Affect

Researchers aiming to define affect should address at least two central issues that concern (a) the distinction between affect, mood, and emotion (Gray & Watson, 2007) and (b) the distinction between state and trait affect (Gray & Watson, 2007; Kanning, Ebner-Priemer, & Schlicht, 2013). Even today, the terms "emotion," "mood," and "affect" are frequently used synonymously (Batson, Shaw, & Oleson, 1992; Scherer, 1984), although there is growing awareness among researchers that these terms considerably differ with respect to certain criteria such as complexity and duration (Ekkekakis, 2012; Table 1). The following three paragraphs will review the current scientific knowledge of what constitutes emotions, mood, and affect.

Emotion is conceptualized as a "complex set of interrelated sub-events concerned with a specific object" (Russell & Feldman Barrett, 1999, p. 806). Thus, an emotion is generally triggered by a particular person, object, or event (i.e., a defining moment) that can be real or imagined and relates to either the past, the present, or the future (Ekkekakis, 2012). The intensity of emotions is usually presumed to be high, the duration short ranging from seconds to minutes at the most (Ekkekakis, 2013; Ekman, 1992). Components of an emotion usually include

> (a) core affect (…), (b) overt behavior congruent with the emotion (e.g., a smile or a facial expression of fear), (c) attention directed toward the eliciting stimulus, (d), cognitive appraisal of the meaning and possible implications of the stimulus, (e) attribution

> to the genesis of the episode to the stimulus, (f) the experience of the particular emotion, and (g) neural (peripheral and central) and endocrine changes consistent with the particular emotion. (Ekkekakis, 2013, p. 41)

Clore and Ortony (2008) concluded that "emotions are cognitively elaborated affective states" (p. 629). In the same line, Lazarus (1991) regarded the cognitive appraisal as the core feature of an emotion. As pointed out by Ekkekakis (2013), emotions direct a person's attention to crucial changes in the environment, and encourage a person to decide or to act.

Mood, a broader concept than emotion, is usually conceptualized as a "more or less persistent state" (Nowlis & Nowlis, 1956). Thus, as opposed to emotions, mood is always present during waking consciousness and is experienced more consistently and frequently with a greater duration that can last hours or even days (Gray & Watson, 2007; Watson, 2000). Moreover, mood is considered to be less intense, more diffuse (due to the fact that mood can occur without the reference to a particular stimulus, Larsen, 2000) and more global than emotions (Ekkekakis, 2012; Morris, 1992). However, like emotions, mood is also based on cognitive appraisal. In the case that mood has a vague object, it is considered to be temporally remote (Morris, 1992). Thus, as opposed to emotions, mood does not closely follow any eliciting stimulus. Mood is known to alter an individual's information processing, for example, through increasing the accessibility to mood-congruent memories.

As pointed out by Russell and Feldman Barrett (2009), *affect* (sometimes also called *core affect*, Russell, 1980) is considered a "neurophysiological state consciously accessible as a simple primitive non-reflective feeling most evident in mood and emotion but always available to consciousness" (p. 104), which is supposedly experienced constantly; however, affect may vary over time with respect to its nature and intensity (Ekkekakis, 2013). This non-cognitive and non-reflective character is the most important feature of affect (Ekkekakis, 2013). As opposed to the more complex, multifaceted constructs of emotions and mood—which also include additional components such as cognitive appraisals, attributions to proximal (internal) or distal (external) eliciting stimuli, and behavioral reactions (e.g., facial expressions or postural adjustments—affect is rather elementary (i.e., general), thus, irreducible, and "needs not to be directed to anything" (Russell & Barrett, 1999, p. 104). Affect can either be a component of emotions or mood; or it can occur independently of both (Ekkekakis & Petruzzello, 2000). Moreover, affect is believed to vary in terms of two underlying orthogonal dimensions (see Russell & Barrett, 1999, for a review), that is, *valence* (subjective evaluation of states as being either good or bad; pleasure versus displeasure) and *activation* or *arousal* (activation of the sympathetic nervous system that can either be measured directly or indirect-ly through self-reports). When combining these two dimensions, four types of affect can be distinguished: (a) *pleasant affect, high activation* (e.g., energetic, vigorous, or excited), (b) *pleasant affect, low activation* (e.g., calm, relaxed), (c) *unpleasant affect, high activation* (e.g., anxious, angry), and (d) *unpleasant affect, low activation* (e.g., fatigued, depressed).

Besides distinguishing emotions and mood from affect, another important issue refers to the distinction between *state* and *trait affect*. Affect can be conceptualized as a temporary, transient, and context-dependent state (Tellegen, 1985; Watson, 2000) or as a stable trait reflecting an individuals' general tendency or disposition to experience a particular affect, regardless of the current situation. Trait affect is generally investigated in studies that focus on durable interindividual differences (Gray & Watson, 2007), whereas state affect is usually the focus of intensive longitudinal studies that examine momentary and time-varying constructs (Kanning et al., 2013). Both state and trait affect, generally have the same underlying structure and are measured using the same self-report instruments (Gray & Watson, 2007); however, while state affect refers to an individual's current affect (i.e., how a person feels right now), trait affect relates to the average or typical affect of an individual (i.e., how a person generally feels).

Taken together, in this dissertation and the related manuscripts, *depressed affect* is defined as a state-like (i.e., transient), non-cognitive, unpleasant affect with low activation that varies over time, possibly due to a change in the environment such as more physical activity than usual (Russell, 2005).

Table 1. *Distinction between Emotion, Mood, and Affect. Adapted from Ekkekakis (2013, pp. 47–48)*

Dimension	**Emotion**	**Mood**	**Affect**
Frequency	Rarely	Most of the time	Always
Duration	Short	Long-lasting	Constant
Intensity	High	Lower than emotion, except for depression	Variable
Components	Yes: core affect, cognitive appraisal, bodily changes, vocal and facial expressions, action tendencies	Yes: but components are less pronounced or less distinct compared to emotions	No

Table 1. *Distinction between Emotion, Mood, and Affect. Adapted from Ekkekakis (2013, pp. 47–48) (continued)*

Dimension	**Emotion**	**Mood**	**Affect**
Object/Stimulus	Yes: specific eliciting stimulus, clearly identifiable	Yes: possibly, rather unspecific, not easily identifiable	Mostly not, not necessarily
Cognitive appraisal	Yes	Yes	Mostly not
Temporal relation to object/stimulus	Immediate or close	Temporarily remote	Direct
Function	To direct attention, coordinate response across multiple channels, communicate	To prepare for future, influence cognition, lower threshold for congruent emotions	To approach or avoid stimuli, prioritize stimuli, alert accessibility to memories
Examples	Depressiveness	Dysphoria	Depressed

1.3.2 Theories of Affect

How to best conceptualize and embed affect within a theory has been the subject of research for years. As pointed out by Russell and Feldman Barrett (1999), there is a variety of model assumptions: some researchers assign various affective states to categories, others to dimensions; some researchers use bipolar concepts, while others prefer unipolar ones; whereas some researchers consider affective states to have a simple structure, others favor a circumplex model or even a hierarchical structure. In general, two approaches, which are not mutually exclusive but rather complementary, have been distinguished: (a) categorical and (b) dimensional models. Which model is considered more suitable depends on the respective research question.

Categorical models consider affect as distinct and independent states or entities (Izard, 1993; Roseman, Wiest, & Swartz, 1994). However, since some states may resemble others (e.g., dejected and depressed), some researchers have grouped similar states together, implying that the states within the same category closely resemble each other but do not resemble the states from other categories (e.g., Russell, 1991). It has been criticized that measures based on categorical models are usually comprised of an assortment of distinct states that researchers deemed relevant at the time of their development (Ekkekakis, 2013). However, the main advantage of the categorical model is that it enables researchers to analyze distinct affective states, such as depressed affect, precisely (Ekkekakis & Petruzzello, 2002).

Dimensional models assume systematic interrelationships between affective states that can be modeled by as few as two basic dimensions that account for similarities and differences between affective states (Ekkekakis, 2013). The primary strength of the dimensional approach is the ability to investigate the entire scope of affect (i.e., core affect) (Ekkekakis & Petruzzello, 2002). However, this perspective lacks the high degree of specificity that can only be reached by the distinct-states (i.e., categorical) approach. The foundation for the dimensional approach was laid in the 1950s by Osgood and colleagues (e.g., Osgood, Suci, & Tannenbaum, 1957) who originally identified three orthogonal (i.e., unrelated), empirically determined dimensions of affective states: (a) an "evaluative" factor that was later called "valence" (i.e., pleasure versus displeasure represented by good versus bad, pleasant versus unpleasant, and positive versus negative), (b) an "activity" factor that was later termed "arousal" or "activation" (characterized by items such as fast versus slow, active versus passive, and excitable versus calm), and (c) a "potency" factor (later also labelled "dominance" or "control"; represented by items such as strong versus weak, large versus small, and hard versus soft) (Ekkekakis, 2013). Since the potency factor referred to antecedents or consequences of affect, rather than to affect itself, this dimension has mostly been excluded from subsequent research (Russell, 1978). Today, there are four variants of the two-dimensional structure (i.e., valence and arousal/activation) that are summarized below.

Russell's circumplex model (Russell, 1980) of core affect assumes two orthogonal, bipolar dimensions: affective valence and perceived activation (Figure 2). All affective states are combinations of these two dimensions. States which are close together within the same sector (e.g., tired and fatigue), show a very similar degree of valence and activation (in this case, negative valence and low activation), whereas states which are diametrically opposed (e.g., tense and relaxed) differ maximally with respect to at least one dimension (in this case, valence and activation). States which are separated by a 90° angle are unrelated (e.g., wired and pleased). The term "circumplex" refers to the assumption that heterogeneous affective states that can be subsumed under more general entities should be arranged around the perimeter of a circle (Feldman Barrett & Russell, 2009). Russell's circumplex model emphasize that dimensions are bipolar, implying that pleasant and unpleasant states are at opposite ends of the same dimension. Thus, according to Russell and Feldman Barrett (2009), a circular, instead of a linear, order of affective states best represents the complexity of their structure. The empirical evidence of Russell's circumplex model was largely based on the analyses of facial expressions and judged similarities (Gray & Watson, 2007). This differentiates Russell's research from that of Watson and Tellegen (1985), which will be outlined in the next paragraph.

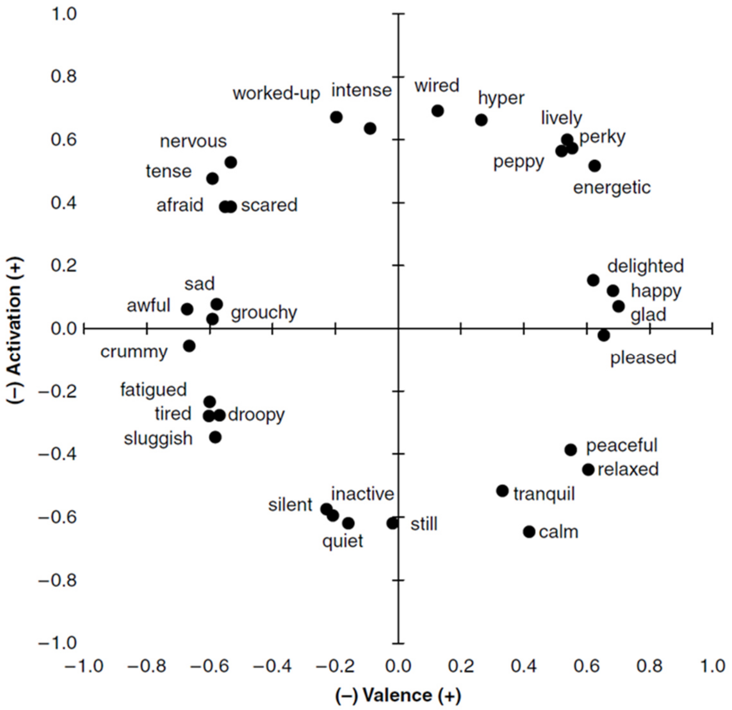

Figure 2. Circumplex model of Russell (1980). Adopted by Ekkekakis (2013).

Watson and Tellegen (1985) expanded Russell's circumplex model by analyzing extensive self-report data. As with Russell's model, the model of *Positive Affect – Negative Affect* of Watson and Tellegen (Watson & Tellegen, 1985) distinguishes two robust dimensions of affective states arranged in a circumplex model on the basis of factor analyses (Figure 3): affective valence (e.g., ranging from happy and pleased to unhappy and sad) and perceived activation, originally labeled as "strong engagement versus disengagement" (e.g., ranging from aroused and astonished to quiescent and still) (Ekkekakis, 2013). Thus, Watson and Tellegen's dimensions (Watson & Tellegen, 1985) were rotated variants of those proposed by Russell (1980). In detail, one Varimax rotated axis of Watson and Tellegen's Positive Affect – Negative Affect model extended from high activation-pleasant affect (e.g., excited) to low activation-unpleasant affect (e.g., sluggish) and the other from high activation-unpleasant affect (e.g., nervous) to low activation-pleasant affect (e.g., relaxed), respectively. For example, "happy" and "sad" indicate two opposite poles of the same dimension (i.e., pleasantness versus unpleasantness) and not orthogonal dimensions of positive and negative affect. Therefore, Watson, Wiese, Vaidya, and Tellegen (1999) changed Positive Affect (pleasure) into Positive Activation and Negative Affect (displeasure) into Negative Activation to avoid misunderstandings.

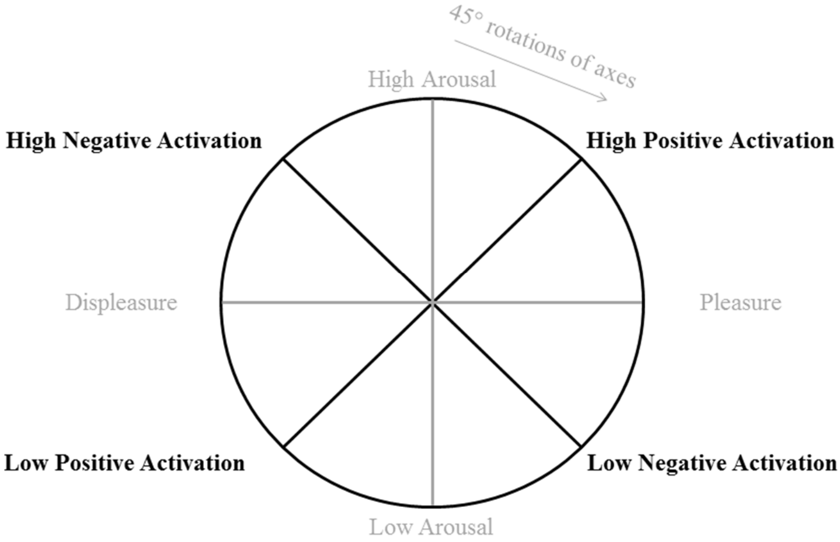

Figure 3. Positive Affect – Negative Affect model of Watson and Tellegen (1985). Adopted by Ekkekakis (2013).

Thayer's two-dimensional model (Thayer, 1978) focuses exclusively on activation and distinguishes two dimensions that are assumed to interact: Activation Dimension A (later called "Energetic Arousal") ranges from energy (e.g., vigorous) to tiredness (e.g., drowsy); Activation Dimension B (later termed "Tense Arousal") ranges from tension (e.g., jittery) to calmness (e.g., placid).

Larsen and Diener (1992) combined the two-dimensional models of Russell (1980), Watson and Tellegen (1985), and Thayer (1978) to an *integrative circumplex model* by dividing the two-dimensional space into octants (Figure 4). One set of orthogonal axes represents the two dimensions of Russell (1980), that is, valence (unpleasant-pleasant) and activation (low activation-high activation), and the other set of orthogonal axes represents Watson and Tellegen's (1985) and Thayer's (1989) 45° rotated versions: from high activation-pleasant affect (e.g., enthusiastic) to low activation-unpleasant affect (e.g., tired) and from high activation-unpleasant affect (e.g., annoyed) to low activation-pleasant affect (e.g., relaxed). Thus, the central idea of the integrative circumplex model is that Watson and Tellegen's Positive Activation and Negative Activation and Thayer's Energetic Arousal and Tense Arousal represent variants of the dimensions of Valence (pleasure-displeasure) and Activation (high arousal-low arousal) proposed by Russell (1980) rotated 45°.

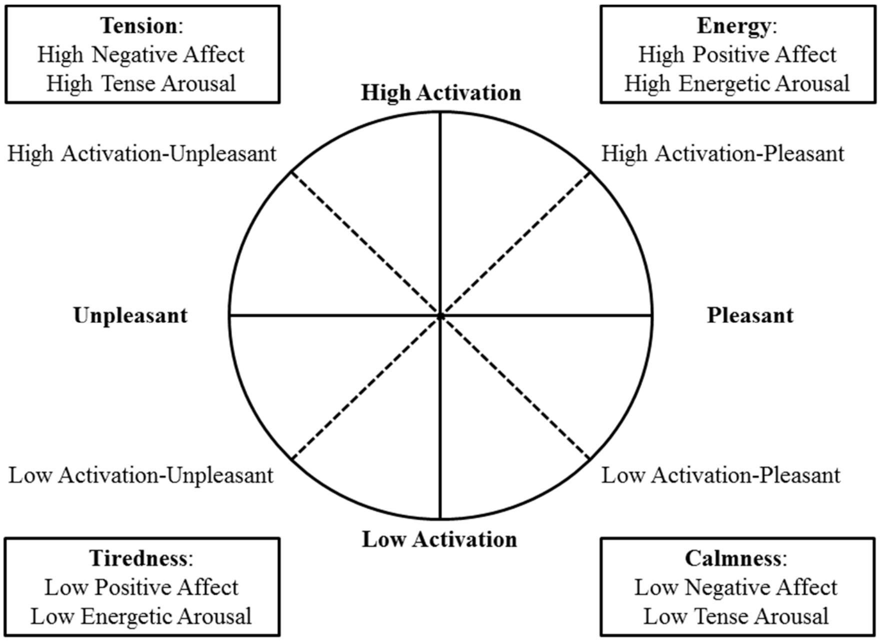

Figure 4. Integrative circumplex model of Larsen and Diener (1992). Adopted by Ekkekakis (2013).

Models with a *hierarchical structure* include both discrete affective states (categorical perspective) and broader dimensions of affect (dimensional perspective) (Ekkekakis, 2013). In an empirically derived, three-level hierarchical model proposed by Tellegen, Watson, and Clark (1999), the highest level relates to Russell's general bipolar dimension of pleasure-displeasure (Russell, 1980). The intermediate level refers to Watson and Tellegen's two orthogonal dimensions of Positive Affect or Positive Activation and Negative Affect or Negative Activation (Watson & Tellegen, 1985). The lowest level relates to discrete affective states.

Taken together, since this dissertation aims to solely investigate the distinct state of depressed affect, the selection of a dimensional approach would have been inappropriate. On the basis of theoretical considerations, we preferred a categorical approach instead. Since we did not intend to study other distinct affective states or to draw conclusions about the global domain of core affect, our approach seems reasonable and theoretically justified.

1.3.3 Measurement of Affect

As pointed out by Ekkekakis (2013) the selection of a measure to quantify participants' affect should follow a theory-driven, funnel-like strategy encompassing three steps. First, researchers must decide which of the three main constructs (i.e., emotion, mood, or affect) should be the target of their investigation. Second, due to the study's objective, researchers have to select from various theories of affective states that model that they consider most appropriate to conceptualize their target construct. As such, researchers should provide adequate, theoretical reasoning for their selection. Third, on the basis of the selected model, researchers must choose a suitable (e.g., change-sensitive), reliable, and valid instrument that meets the study's requirements best (e.g., as few items as possible versus a multi-item self-report).

At the present time, there is a variety of instruments for assessing state affect. As stated by Ekkekakis (2013), since most self-reports on mood usually measure affect, researchers have to carefully consider the distinguishing features of mood and affect described earlier. Measures of discrete affective states generally refer to particular structural models, implicitly or explicitly. As outlined previously, two primary approaches can be distinguished: categorical models focusing on specific affective states and dimensional models viewing affect as a combination of a few general dimensions (Gray & Watson, 2007; Watson, 2000).

Since Manuscript II and III exclusively investigate adolescents' depressed affect as a discrete state, instruments measuring affect dimensions (e.g., Activation-Deactivation Adjective Checklist, Thayer, 1967; Affect Grid, Russell, Weiss, & Mendelsohn, 1989; Positive and Negative Affect Schedule, Watson, Clark, & Tellegen, 1988) are not the subject of this dissertation (see Ekkekakis, 2013; Gray & Watson, 2007, for an overview). Instruments which assess discrete affective states are, for example, the Multiple Affect Adjective Checklist (MAACL, Zuckerman & Lubin, 1965), the Expanded Form of the Positive and Negative Affect Schedule (PANAS-X, Watson & Clark, 1999), and the Profile of Mood States (POMS, McNair et al., 1971). Since in Manuscript II and III, we measured adolescents' current depressed affect by means of the POMS, the following paragraph will describe this particular instrument in detail.

The POMS—originally developed as the Psychiatric Outpatients Mood Scale (McNair et al., 1971) to study a patient's typical affective state and changes in affect due to treatment—is among the most popular self-report measures, not only in psychiatric and physically ill patients but also in healthy people of various ages (Curran, Andrykowskim, & Studts, 1995). Particularly in physical activity research, the POMS has been extensively used (Ekkekakis, 2013). The long-form of the POMS contains 65 adjectives covering six domains: anger, confusion, depression, fatigue, tension, and vigor. Items are rated on a 5-point Likert scale (mostly unipolar response format) that ranges from 0 (*not at all*) to 4 (*extremely*). Depending on the particular research question, the POMS can be administered with various time frames, ranging from "right now" (current state affect) to "the past month, including today" (general trait affect). It is important to know that McNair and colleagues (1971) did not attempt to develop an instrument that assesses core affect, that is, the entire scope of affect. Instead, they rather aimed to design a measure of specific affective states. In addition to the original 65-item version of POMS, several abbreviated versions have been developed (e.g., Cranford et al., 2006; Lane & Lane, 2002; Shacham, 1987), making the POMS particularly suitable for the use in intensive longitudinal studies. In this dissertation, we used one of the shortened versions of the POMS, that is, the 3-item subscale (sad, discouraged, and hopeless) of the POMS-15 (Cranford et al., 2006) to measure within-person change in adolescents' depressed affect reliably.

With respect to the factor structure of the POMS, on the basis of a Varimax rotation, Lorr, Shi, and Youniss (1989) examined the first two principal components: One component represented pleasant versus unpleasant affect and the other energetic arousal versus drowsy fatigue. Since the item pool of the POMS seems less balanced than that of Russell (1980) and Watson and Tellegen (1985), the factor solution of Lorr and colleagues (1989) was not congruent with the models proposed by the other aforementioned authors but converged, however, at least to some extent with the two-dimensional circumplex model (pleasantness and arousal). With regard to the quality criteria, the POMS demonstrated acceptable internal consistency and moderate stability over short time periods (Gray & Watson, 2007), implying that the POMS is sensitive to change (McNair & Lorr, 1964; Payne, 2001). Moreover, the POMS revealed good predictive validity and good to excellent concurrent validity with scales such as the Beck Depression Inventory, a self-report instrument measuring the severity of depression (Lane & Lane, 2002; Payne, 2001).

As most other self-report instruments of affect, the POMS has several limitations; the two main points of criticism will be addressed below. First, since the POMS was originally developed for psychiatric outpatients, the a priori selection of items that constituted the six factors was driven by the authors' clinical judgement and experience (i.e., selection was not based on common test construction procedures), rather than by empirical evidence (Ekkekakis, 2013). This implies that the authors failed to provide a guiding theoretical model to explain how items were selected, whether the derived factors were expected to interact, and how they could have been separated from each other (Spielberger, 1972; Thayer, 1989). Second, the POMS includes only six distinct affective states (as already mentioned without a conceptual or empirical basis), thereby omitting affective domains such as cheerfulness and serenity that are particularly interesting to study for physical activity researchers. Thus, on the basis of the POMS, researchers are not able to generalize to the global domain of core affect. Third, other researchers (most commonly representatives of dimensional affect models) have criticized that the results on the factor structure of the POMS were rather inconsistent (Ekkekakis, 2013).

Taken together, the current dissertation follows Ekkekakis' (2013) three suggestions which were described at the beginning of this subchapter. Since, in Manuscript II and III, we aimed to study fluctuations of a single transient, non-cognitive affective state (i.e., depressed affect) instead of several dimensions of core affect, we chose the categorical model for measuring our target construct. We preferred the POMS to other self-report instruments for measuring discrete affective states for several reasons: First, the POMS matches the basic assumptions of the discrete (i.e., categorical) model which corresponds to our theoretical considerations best. Second, the POMS assesses depressed affect more briefly than the MAACL (Zuckerman & Lubin, 1965), for example, which is essential for conducting intensive longitudinal studies. Third, as opposed to the PANAS-X (Watson & Clark, 1999), which only assesses sadness (sad, blue, downhearted, alone, and lonely), the POMS measures our target construct of depressed affect much more precisely. Fourth, the POMS is among the very few self-report measures that have been proven to reliably detect within-person change processes of depressed affect (e.g., Cranford et al., 2006).

1.3.4 Review of the Physical Activity-Depressed Affect Findings in Adolescents

Most previous research that has investigated the association between physical activity and depressed affect among adolescents has focused on the between-person level. In other words, these studies have aimed to examine whether adolescents with more physical activity on average show less depressed affect than adolescents with less physical activity on average. The majority of these studies have followed cross-sectional designs; longitudinal studies and randomized controlled trials that enable researchers to draw conclusions about the temporal and causal relationships are much rarer (Mammen & Faulkner, 2013). In most of these studies, physical activity is assessed through retrospective self-reports, which are susceptible to response and recall bias as well as heuristic use and, by association, are considered less reliable and valid due to an overestimation of physical activity and an underestimation of sedentary behavior, respectively (Adamo et al., 2009). Moreover, in randomized controlled trials, physical activity is usually conceptualized as prescribed, structured, and supervised exercise under laboratory conditions and not as self-initiated, unsupervised leisure physical activity in adolescents' everyday life, which thereby reduces the generalizability of results. Compared to longitudinal and intervention studies, studies with an intensive longitudinal design are even more seldom (Biddle & Asare, 2011; Hume et al., 2011; Kanning et al., 2013), although they have many advantages over studies with cross-sectional, longitudinal, and intervention designs. Intensive longitudinal studies are characterized by repeated measurements within everyday contexts to examine change processes within individuals. The two key advantages of intensive longitudinal studies include the fact that they systematically examine naturally occurring processes from day-to-day or within the same day; that is, for example, temporal links between adolescents' unstructured everyday physical activity, best measured directly through motion sensors, and their current depressed affect. This particular study design enables researchers to reduce recall bias and to enhance the ecological validity of results (Reis, 2012). Moreover, researchers that focus on within-person processes can rule out explanations through stable between-person differences, such as socioeconomic status, thereby improving the interpretability of results.

The following subchapter focusses on (a) reviews and meta-analyses examining the between-person association between unstructured physical activity and structured exercise programs and depressive symptoms among adolescents (cross-sectional, prospective longitudinal, and intervention studies), and (b) a review and three original articles investigating the within-person association between unstructured, naturally occurring physical activity and transient states of depressed or (more broadly defined) negative affect (intensive longitudinal studies).

Janssen and LeBlanc (2010) reviewed six studies (three cross-sectional studies and three randomized controlled trials) examining the relationship between physical activity and depressive symptoms among children (8-12 years; two randomized controlled trials) and adolescents (13-19; three cross-sectional studies and one randomized controlled trial). All cross-sectional studies used self-report instruments to measure physical activity. Relations between physical activity and depressive symptoms were either insignificant (Haarasilta, Marttunen, Kaprio, & Aro, 2004) or small to modest (Brosnahan, Steffen, Lytle, Patterson, & Boostrom, 2004; Tao et al., 2007). All three experimental studies (Annesi, 2005; Goldfield, 2007; Norris, Carroll, & Cochrane, 1992) showed small to modest effects of aerobic exercise (8-12 week programs with 60-90 minutes of exercise per week) on adolescents' depressive symptoms.

In a systematic review of prospective, longitudinal studies with at least two measuring points, Mammen and Faulkner (2013) examined whether mostly self-reported physical activity, including exercise and physical fitness, is protective against the onset of depression in adolescents and adults. All together 30 studies of modest to high methodologic quality were included for analyses. A total of 25 studies showed that baseline physical activity of varying intensities was negatively associated with a risk of developing subsequent depression. Thus, results showed promising evidence that physical activity may serve as a valuable prevention strategy against future depression. However, it should be noted that this review includes predominantly studies with adults; only four studies examined adolescents under the age of 18 years. Moreover, the authors did not specify the type and intensity of physical activity that had been examined in the studies cited, and all but one study measured physical activity through self-reports. With regard to the investigations that studied adolescents, all four studies were of modest methodologic quality and only two of them found an inverse relationship between baseline physical activity and follow-up depression (Jerstad, Boutelle, Ness, & Stice, 2010; Sund, Larsson, & Wichstrom, 2011), while the other two did not (Rothon et al., 2010; Weyerer, 1992). Over a 6-year period, Jerstad and colleagues (2010) showed a bidirectional relationship between the total number of physical activities adolescents had performed more than 10 times in the past year during their leisure time and depression in young women (average age at baseline: 13 years). Sund and colleagues (2011) studied young women and men (average age at baseline: 14 years) and revealed that low levels of self-reported vigorous physical activity (hours per week) at baseline was a risk factor for developing depressive symptoms one year later.

Larun and colleagues (2006) reviewed five lower quality vigorous exercise interventions versus no intervention (Beffert, 1994; Berger, 1988; Goodrich, 1984; Hilyer, 1982; Roth, 1987) on depressive symptoms in the general population of children and adolescents (aged between 11 and 19 years). The authors showed a significant moderate effect of physical activity on depressive symptoms (standard mean difference effect size = -0.66; 95% CI -1.25, -0.08). However, since the studies reviewed showed lower quality and were highly heterogeneous with respect to the population studied and the intervention and measurement instruments used, results should be interpreted with caution.

Brown, Pearson, Braithwaite, Brown, and Biddle (2013) conducted a meta-analysis based on nine higher quality randomized controlled trials, either randomized at the school (Annesi, 2005; Mendelson et al., 2010; Norris et al., 1992), class (Bonhauser et al., 2005; Melnyk et al., 2009), or individual level (Daley, Copeland, Wright, Roalfe, & Wales, 2006; Hilyer et al., 1982; MacMahon & Gross, 1988; Petty, Davis, Tkacz, Young-Hyman, & Waller, 2009). Six interventions referred to aerobic exercise (9-40 week programs with sessions lasting 20-90 minutes being held on two to 5 days per week); the others comprised health education, physical education classes, and yoga. Results showed an overall small but significant effect for physical activity on depressive symptoms in children and adolescents aged between 9 and 18 years (Hedges' $g = -0.26$, $SE = 0.09$, 95% CI = -0.43, -0.08, $p = .004$).

Liao, Shonkoff, and Dunton (2015) reviewed four intensive longitudinal studies in adults examining short-term within-person associations between everyday physical activity and subsequent negative (not depressed) affect. Two out of four studies yielded a significant decrease in negative affect after participation in everyday physical activity (Gauvin, Rejeski, & Norris, 1996; LePage & Crowther, 2010), whereas the other two studies found no significant association at the within-person level (Mata et al., 2012; Wichers et al., 2012). Thus, the current evidence that speaks for physical activity in alleviating subsequent negative affect is inconclusive.

Up until now, there have only been three intensive longitudinal studies that have examined the day-to-day association between everyday physical activity and current depressed affect in children (Dunton et al., 2014; Kühnhausen, Leonhardt, Dirk, & Schmiedek, 2013) and adolescents (Gawrilow, Stadler, Langguth, Neumann, & Boeck, 2016). Neither Dunton and colleagues (2014) nor Kühnhausen and colleagues (2013) were able to show a within-person association between physical activity and negative (not depressed) affect, possibly due to methodological restrictions such as participants' young age, item selection, and scale reliability. Gawrilow and colleagues (2016) showed that on days when adolescents had taken more steps than usual they reported less evening depressed affect than on days with fewer steps than usual. Taken together, the exceedingly small number of intensive longitudinal studies in this particular age group as well as the diverse measurement approaches applied in these studies have thus far limited researchers' ability to draw conclusions.

1.3.5 Open Research Questions with Respect to Depressed Affect

With respect to the within-person physical activity-depressed affect link in adolescents, the open research questions listed below target (a) a study's research perspective (within-person/individual level versus between-person/population level), (b) its approach for measuring physical activity and depressed affect (state- versus trait- like variables, prospective or real-time versus retrospective assessment) as well as possible moderating effects.

The majority of studies investigating the association between adolescents' physical activity and depressed affect have revealed cross-sectional (Janssen & LeBlanc, 2010), mid- and long-term longitudinal (Mammen & Faulkner, 2013), as well as intervention designs (Brown et al., 2013; Larun et al., 2006). These reviews and meta-analyses described and evaluated predominately those studies having conducted between-person analyses of mostly retrospective reports on physical activity and depressed affect being susceptible to response and recall bias. The goal of studying between-person associations is to answer the question of whether people who perform more physical activity on average show less depressed affect than people who perform less physical activity on average. In these studies, both physical activity and depressed affect have generally been conceptualized as trait-like processes that do not change over time and situations, at least not in the short-term (Hamaker, 2012). In addition, researchers studying between-person associations commonly also investigate the impact of structural (e.g., intensity of physical activity) as well as dispositional (e.g., gender, age, socioeconomic status) variables that distinguish groups of people (Kanning et al., 2013). Researchers aiming to address the dynamic associations (i.e., change processes) between state-like variables and study whether short-term associations are affected by time-varying situational factors (not stable between-person differences; Bolger et al., 2003; Kanning et al., 2013) should use a prospective or real-time assessment approach with several repeated measurements over time within real-world settings, that is, an intensive longitudinal design (Bolger et al., 2003; Bolger & Laurenceau, 2013; Ebner-Priemer & Trull, 2009). In addition, Hamaker (2012) pointed out that researchers should always keep in mind that results at the between-person level cannot be translated to the within-person (i.e., intraindividual) level that easily. Therefore, to clarify whether everyday physical activity might be an appropriate method to alleviate adolescents' depressed affect, intensive longitudinal studies are the method of choice (Bolger & Laurenceau, 2013). However, although studying dynamic change processes between physical activity and depressed affect seems very important among adolescents, since they are at high risk for inactive lifestyle and depressed affect (Thapar et al., 2012; Nader et al., 2008), intensive longitudinal studies with adolescents are very rare. So far, there have only been three intensive longitudinal studies in children (Dunton et al., 2014; Kühnhausen et al., 2013) and young adolescents (Gawrilow et al., 2016), that have investigated the within-person association between physical activity and affect with mixed results. In adults, the data situation is slightly better, but still patchy (Kanning et al., 2013). Thus, taken together, future research should focus on adolescents as an important target group for studying the dynamic associations between physical activity and depressed affect within-person using an intensive longitudinal approach. With regard to the dose-response relationship between physical activity and depressed affect, future studies should also quantify the additional amount of time spent on a particular physical activity intensity level that is required to reduce adolescents' depressed affect.

Concerning the measurement of depressed affect, elaborate measures usually containing a large number of items are used to quantify depressed affect, particularly in studies with a cross-sectional, mid- and long-term longitudinal, and intervention design. However, these measures are generally not feasible for intensive longitudinal studies due to the already substantial burden on participants, imposed by the high measurement frequency, a key feature of intensive longitudinal studies (Cranford et al., 2006). Moreover, these measures, which are mostly administered only once, commonly consist of items that usually refer to a time interval in the past (yesterday, last week, last two weeks or last month) that may lead to systematic distortions. The retrospective assessment of depressed affect might be more appropriate for studying between-person associations as well as for diagnosis; however, it is unsuitable for assessing immediate, real-time variations of depressed affect. Since these measures were originally developed for studying between-person differences, their sensitivity to within-person change is mostly unknown (Cranford et al., 2006). In addition, most of these measures have not been used within adolescent samples, implying that it is still largely unclear whether these scales can be regarded as reliable instruments for this particular age group. For example, within adult samples, Cranford and colleagues (2006) demonstrated that an abbreviated 3-item subscale of the POMS (McNair et al., 1971) is reliable for measuring depressed affect within person. Whether this is also true for adolescents has not been studied yet. Moreover, the very few intensive longitudinal studies in adolescents have predominantly focused on broad categories of positive and negative affect and not on depressed affect, in particular (Kanning et al., 2013). Thus, future studies should evaluate the sensitivity of shortened depressed affect scales to within-person change among adolescents, that is, they should test whether these items are suited for reliably detecting dynamic processes within adolescents in natural settings over time. With regard to physical activity assessment, future studies investigating the within-person association between adolescents' physical activity and depressed affect should use direct measures to assess current, real-time physical activity to reduce recall bias (Kanning et al., 2013). Moreover, given that both gender and day of the week (i.e., weekday versus weekend day) have an impact on physical activity (more physical activity in young men and on weekdays, Hallal et al., 2012; Nader et al., 2008) as well as depressed affect (higher depressed affect in young women and on weekdays, Cranford et al., 2006), these factors should be examined in future research as potential moderators of the within-person association between adolescents' physical activity and depressed affect.

1.4 ADHD as a Moderator of the Physical Activity-Depressed Affect Link in Adolescents

Starting with a definition of ADHD and an overview of various approaches to measure ADHD symptoms in adolescents, the next section will review prior research on the impact of physical activity on depressed affect in adolescents at risk for and diagnosed with ADHD. Finally, open research questions will be summarized.

1.4.1 Definition of ADHD

Attention-deficit/hyperactivity disorder (ADHD) is considered a neurodevelopmental disorder which is characterized by symptoms of inattention (e.g., inability to focus one's attention to details, difficulty to sustain attention, being easily distracted, forgetting and losing things, inability to structure and organize tasks in a targeted manner), hyperactivity (e.g., fidgeting, squirming, difficulty to remain seated, extreme restlessness), and impulsivity (e.g., excessive talking, difficulty to wait, interrupting others, blurting out answers before questions have been completed). According to the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; American Psychiatric Association, APA, 2013), three manifestations of ADHD can be distinguished that can change throughout life: (a) predominantly inattentive, (b) predominantly hyperactive-impulsive, and (c) combined inattentive and hyperactive-impulsive. According to the *International Classification of Diseases* (ICD-10; WHO, 2015) four subtypes of hyperkinetic disorders can be distinguished: (a) disturbance of activity and attention (equivalent to the DSM-5 combined inattentive and hyperactive-impulsive manifestation), (b) hyperkinetic conduct disorder, (c) other hyperkinetic disorders, and (d) hyperkinetic disorder, unspecified. Both diagnostic systems state that ADHD symptoms must be present in multiple settings (e.g., at home, at school or work, while staying with friends, during other leisure activities). Based on the DSM-5, at least six out of 18 symptoms of inattention and/or hyperactivity-impulsivity must occur in children and adolescents; symptoms have to persist for at least six months and must interfere with an individual's developmental stage and functioning. Based on the ICD-10, an ADHD diagnosis requires at least six out of 10 symptoms of inattention, at least three out of five symptoms of hyperactivity, and at least one out of four symptoms of impulsivity; as with the DSM-5, all symptoms have to persist for at least six months and must interfere with an individual's developmental stage and functioning. Despite the similarity of the DSM-5 and the ICD-10, manifestations of ADHD, diagnostic criteria (including required number of symptoms, age of onset, and course of disease, for example), and exclusion criteria vary between the two diagnostic systems (see APA, 2013; WHO, 2015, for more information on ADHD diagnostic criteria). According to Barkley (2014a), an individual's difficulty to self-regulate one's emotions is another important feature of ADHD, although this is not a diagnostic criterion. In addition, adolescents at risk for or with diagnosed ADHD commonly suffer from comorbid, particularly affective symptoms such as depressed affect (e.g., Blackman, Ostrander, & Herman, 2005; Daviss, 2008).

While the DSM-5 assumes a two-dimensional structure of ADHD (inattention and hyperactivity-impulsivity), the ICD-10 emphasizes a three-dimensional structure (inattention, hyperactivity, and impulsivity) with all symptom dimensions being interrelated, though conceptually independent (correlated two- and three-factor model of ADHD, respectively) as the central feature of ADHD (Schmid, Stadler, Dirk, Fiege, & Gawrilow, accepted). Current research questions whether the underlying structure of ADHD symptoms might be better described using a bifactor model with a general ADHD factor and two to three specific symptom factors which are unrelated to the general factor (Schmid et al., accepted). Moreover, the DSM-5 and the ICD-10 both address solely stable, trait-like between-person (interindividual) differences of ADHD symptoms between adolescents. However, one of the most intriguing questions is whether ADHD symptoms can also be conceptualized as transient, state-like within-person (intraindividual) fluctuations (Schmid et al., 2016). Despite these current issues and developments in ADHD research, this dissertation focuses exclusively on trait hyperactivity assessed by means of a single screener item of one symptom of hyperactivity. Details on the measurement of ADHD symptoms will be described in the following section.

1.4.2 Measurement of ADHD Symptoms

In accordance with the clinical gold standard, psychological assessment of ADHD symptoms should incorporate various measurement methods (i.e., interviews, rating scales, psychological testing, and direct behavioral observation) across several informants (i.e., adolescents, parents, other family members, teachers, peers, and clinicians), and multiple situations (Barkely, 2014b). Subsequently, possibly existing comorbid disorders, especially depression, should be examined, as well (Barkely, 2014b). Since, as opposed to clinicians, researchers do not provide a diagnosis, they commonly use only individual, less time-consuming methods to assess ADHD symptoms, for example, by administering surveys to adolescents and, sometimes, to parents and teachers, respectively. Among the most commonly used rating scales of ADHD symptoms for adolescents (Pliszka & AACAP Work Group on Quality Issues, 2007) are the screening instruments Child Behavior Checklist (CBCL/6-18; Achenbach & Rescorla, 2001), Teacher's Report Form (TRF/6-18; Achenbach & Rescorla, 2001), and Youth Self-Report (YSR/11-18; Achenbach & Rescorla, 2001), as well as the more specific instruments of the Conners 3 (Conners, 2008), available as self-, parent-, teacher-report versions. Besides these very extensive assessment tools, researchers mostly tend to apply shorter (screening) instruments, such as the Strengths and Difficulties Questionnaire (SDQ) for adolescents, parents, and teachers (Goodman, 1997), due to time constraints. The SDQ has been validated against the CBCL with the result that the SDQ has been shown to be an equally valid instrument for research purposes (Goodman & Scott, 1999; Klasen et al., 2000).

In general, instruments for measuring ADHD symptoms are mostly used for quantifying individual stable traits at a single date as well as long-term changes of ADHD symptoms between individuals over months and years (Faraone, Biederman, & Mick, 2006). Instruments developed for assessing especially transient (e.g., day-to-day), state-like changes of single ADHD symptoms, such as hyperactivity within individuals with several repeated measurements over time within real-world settings, are, however, still lacking (Schmid, 2014). In a recent intensive longitudinal study, Schmid and colleagues (accepted) demonstrated that self-reported ADHD symptoms in a sample of adolescents diagnosed with ADHD fluctuated substantially within individuals from day to day. These fluctuations might have been due to changes in situational and personal factors, such as school settings (Imeraj et al., 2016; Rapport, Kofler, Alderson, Timko, & DuPaul, 2009) and physical activity participation (Gapin, Labban, & Etnier, 2011), which have been shown to impact ADHD symptoms in the short-term. Thus, instruments that assess day-to-day changes of ADHD symptoms within adolescents are much-needed.

Besides self- and proxy-reports of adolescents' ADHD symptoms, for the near future, one of the most promising assessment approaches for quantifying hyperactivity directly (conceptualized as increased spontaneous movements and physical activity) are motion sensors such as accelerometers. Although researchers' interest in directly measuring hyperactivity is constantly growing, studies examining within-person changes in adolescents' hyperactivity through direct measures do not yet exist (Gawrilow, Kühnhausen, Schmid, & Stadler, 2014).

At the time our intensive longitudinal study on hyperactivity as a moderator of the within-person association between adolescents' physical activity and depressed affect was conducted (Manuscript II), suitable measurement tools for assessing within-person change processes of adolescents' hyperactivity were missing. Therefore, and because we wanted to keep participants' burden as low as possible, we decided to measure hyperactivity as a trait-like, stable construct, using one of the two hyperactivity items of the self-report version of the SDQ (Goodman, 1997) that we thought would best describe the core symptom of hyperactivity ("I constantly fidget or squirm"; see Manuscript II, for further details on the SDQ).

1.4.3 Review of the Physical Activity-Depressed Affect Findings in Adolescents with ADHD

Only recently, researchers have begun to investigate the effects of acute and regular physical activity on ADHD symptoms; however, mostly among children (e.g., Gapin & Etnier, 2008; Medina et al., 2010; Pontifex, Saliba, Raine, Picchietti, & Hillman, 2013; Verret, Guay, Berthiaume, Gardiner, & Béliveau, 2010; see Gapin et al., 2011; Neudecker, Mewes, Reimers, & Woll, 2015, for reviews). So far, there have been very few studies that have investigated the effect of *acute* physical activity on children's ADHD symptoms. Medina and colleagues (2010) studied the impact of a single 30-minute session of vigorous-intensity physical activity (treadmill running) on the sustained attention of 25 boys with ADHD. The authors found that acute bouts of physical activity improved sustained attention performance (i.e., response times and vigilance) and reduced impulsivity in children with ADHD, irrespective of medication treatment. In a randomized controlled trial (RCT), Pontifex and colleagues (2013) examined the effect of a single 20-minute bout of MVPA (treadmill running) in 20 boys and girls with ADHD and 20 healthy matched controls. The authors found that particularly children with ADHD showed improved inhibitory control and neurocognitive functions after 20 minutes of MVPA compared to 20 minutes of seated reading. In addition, only few studies have investigated the effect of *regular* physical activity on ADHD symptoms; however, again, predominantly among children. Verret and colleagues (2010), for example, conducted a RCT to examine the impact of a 10-week structured MVPA program (45-minute sessions, 3 times a week including a warming-up period, progressive aerobic, muscular, and motor skills exercises, and a cooling-down period) on physical fitness, motor performance, cognitive functioning (information processing, sustained attention), and ADHD symptoms among 18 children with ADHD. Children in the treatment group showed better information processing and sustained attention and their parents reported fewer attention problems and fewer overall behavioral problems at follow-up than at baseline compared with children in the control group. Gapin and Etnier (2010) studied 18 boys with ADHD and found that more MVPA over a 7-day period predicted improved executive function performance such as better planning abilities. In their review on the effects of physical activity, Gapin and colleagues (2011) stated that—despite from the very limited body of literature—there is some evidence that enhanced physical activity improves children's cognitive performance and ADHD symptoms. Neudecker and colleagues (2015) emphasized that particularly multifaceted exercise programs, including team sports, coordinative training, and body perception, seem to improve physical, mental, and social well-being in children and adolescents with ADHD most effectively.

Children and adolescents with ADHD also frequently suffer from comorbid disorders, and in particular from depressive symptoms such as depressed affect (Biederman et al., 2008; Chronis-Tuscano et al., 2010; Daviss, 2008). Problems with affective regulation (i.e., lack of strategies for modulating the type and/or magnitude of affective states; Gross & Thompson, 2010) are likely to elevate the risk for depressive symptoms in adolescents with ADHD, suggesting that affective regulation mediates the association between adolescents' ADHD and depressive symptoms (Seymour et al., 2012). Considering this, children and adolescents with ADHD might especially benefit from interventions, such as physical activity, that are supposed to improve affective states. Until now, however, only very few studies have examined the potential benefits of physical activity on depressed affect in children and adolescents with ADHD (Kiluk, Weden, & Culotta, 2009; Jensen & Kenny, 2004; Verret et al., 2010). In a RCT (Verret et al., 2010), teachers reported lower levels of anxiety-depression (composite score) among children with ADHD of the treatment group compared to children with ADHD of the control group. In a cross-sectional study based on the reports of parents, Kiluk and colleagues (2009) found that engaging in at least three sports throughout the year was associated with fewer anxious and depressive symptoms among children with ADHD compared to children with ADHD who participated in a maximum of two sports throughout the year. In a RCT, Jensen and Kenny (2004) examined the effects of a structured 20 session yoga program (one 60-minute session per week) in 19 boys with ADHD. All participants showed a reduction in ADHD symptoms. In addition, children of the treatment group showed greater improvement in emotional stability compared to children of the control group (cooperative activities).

1.4.4 Open Research Questions with Respect to the Physical Activity-Depressed Affect Link within Adolescents at Risk for ADHD

With respect to the within-person association between physical activity and depressed affect among adolescents with varying levels of hyperactivity, open research questions that are described below focus on (a) methods for measuring adolescents' everyday physical activity and depressed affect over time within real-world settings, as well as study design, (b) hyperactivity as a moderator of this within-person link, and (c) the dose-response relationship between physical activity and depressed affect among adolescents.

To date, there have been only very few studies that have examined the effects of physical activity on depressed affect among children diagnosed with ADHD, with most of them showing cross-sectional and intervention designs. However, so far, studies investigating adolescents and studies following an intensive longitudinal design are lacking, although this design is considered the method of choice when studying the effects of everyday physical activity on depressed affect. In the very few existing cross-sectional studies and RCTs, physical activity has often been conceptualized as a trait-like construct, exclusively assessed through retrospective parent- and teacher-reports, which are known to be less reliable and valid than pedometers, for example. Moreover, instead of self-initiated everyday physical activity, previous studies have focused solely on structured and supervised exercise, reducing the ecological validity as well as the generalizability of results. In addition, these studies investigated depressed affect as a trait-like construct and used retrospective proxy-reports. However, since depressed affect in children and adolescents is generally difficult to recognize from the outside (i.e., by parents or teachers), whenever possible, depressed affect should be assessed by means of self-reports. When using intensive longitudinal designs, applied items should be sensitive, in order to detect within-person change in adolescents. The reliability of items for measuring depressed affect in adolescents has not yet been tested. Taken together, intensive longitudinal studies measuring real-time variations of physical activity and depressed affect across several consecutive days within real-world settings are required to quantify possible antidepressant effects of physical activity more precisely. Moreover, studying this association, not only among adolescents diagnosed with ADHD but also among healthy adolescent with varying levels of subthreshold hyperactivity, might increase generalizability. Given that ADHD symptoms, such as hyperactivity and depressed affect, are comorbid conditions, in particular adolescents with varying levels of hyperactivity should benefit from more-than-usual physical activity, as this is believed to improve adolescents' depressed affect. With regard to the dose-response relationship between physical activity and depressed affect, future studies should quantify the additional amount of physical activity (e.g., steps taken per day) that is required to reduce adolescents' depressed affect.

2. Manuscripts I–III: Summaries

This dissertation is based on three manuscripts that investigate adolescents' barriers to everyday physical activity, within-person associations between adolescents' daily physical activity and next-morning or same-evening depressed affect, as well as moderators of this link (e.g., hyperactivity, gender, and day of the weekday). In the following section, the theoretical background and research objectives, methods, results, and conclusions of each manuscript will be briefly summarized and discussed, respectively.

2.1 Summary for Manuscript I

Citation: Langguth, N., Könen, T., Matulis, S., Steil, R., Gawrilow, C., & Stadler, G. (2015). Barriers to Physical Activity in Adolescents: A Multidimensional Approach. *Zeitschrift für Gesundheitspsychologie, 23*, 47–59. doi:10.1026/0943-8149/a000136

Background and Objectives

In general, barriers to physical activity are understood as constraints that might hamper or impede an individual's physical activity participation. Among adults, barriers to physical activity are considered one of the most important correlates of physical activity. Among adolescents, barriers to physical activity are also a well-studied construct; however, results are more ambiguous for various reasons. These include (a) varying definitions of barriers to physical activity, (b) lack of differentiation between barriers and other psychosocial correlates such as negative outcome expectations or self-efficacy, (c) lack of or wide discrepancies in theoretical embedding (discrete construct versus part of behavioral control or self-efficacy), (d) and diverse measurement methods (e.g., uni-, two- versus multiple barrier dimensions; researcher-generated scales versus focus groups). This heterogeneity makes it very hard for researchers to compare results across studies and to draw general conclusions. To date, valid questionnaires measuring adolescents' most important barriers to physical activity are largely missing. The purpose of Study 1 (item development) and Study 2 (questionnaire validation) was to gain a better understanding of the entire spectrum of adolescent-generated barriers to physical activity that are relevant to adolescents' particular developmental stages as well as their everyday reality. Deeper insight into the nature and dimensionality of barriers seems essential for the promotion of adolescents' physical activity participation. This insight is of the utmost importance, since physical activity decreases sharply and substantially during the transition to adolescence with possible short- and long-term consequences for their physical and mental health.

Methods

In Study 1 (qualitative approach), 118 adolescents (age: M = 18.17, SD = 3.08 years, range: 12-24 years; 68% males; 56% with an immigrant background; 64% meeting physical activity guidelines) reported their most important barriers to physical activity and wore accelerometers. Participants were instructed to write down up to six situations, events, people, thoughts, or feelings that kept them from being physically active during the previous week.

Study 1 aimed to obtain as many adolescent-generated multifaceted barriers to physical activity as possible.

In Study 2 (quantitative approach), 598 adolescents (age: *M* = 17.44, *SD* = 1.98 years, range: 13-21 years; 68% males; 43% with an immigrant background; 56% meeting physical activity guidelines) completed a pre-version of our newly developed questionnaire (instructions: "Several situations are listed below that may keep adolescents from being physically active. Please indicate how strongly each barrier kept you from being physically active during the last week") using a 4-point Likert scale ranging from 1 (*not at all*) to 4 (*very much*). Adolescents were additionally asked to report their overall physical activity, intention, self-efficacy, and negative outcome expectations with reference to the previous week (validity criteria). Study 2 aimed to (a) examine the dimensional structure of 46 adolescent-generated barriers to physical activity, (b) compare the fit indices of a multidimensional model to those of a uni- and two-dimensional model, and (c) determine criterion (association between barrier dimensions and physical activity as well as intention) and discriminant validity (association between barrier dimensions and self-efficacy as well as negative outcome expectations). We expected that (a) a multidimensional model would show a better model fit than a uni- and two-dimensional model (Hypothesis 1), (b) derived barrier dimensions would correlate negatively with (particularly vigorous) physical activity and intention (criterion validity; Hypothesis 2), and (c) derived barrier dimensions would correlate negatively with self-efficacy and negative outcome expectations (discriminant validity; Hypothesis 3).

Results

In Study 1, two coders grouped 10% of barriers to physical activity together and resolved disagreements by discussion (preliminary, literature-based categories: cognitive, emotional, motivational, physical, social, environmental, institutional barriers to physical activity, lack of equipment and money, other leisure activities, and sedentary activities). Overall, 602 barriers were classified; on basis of these, 46 most commonly cited, multifaceted barriers to adolescents' physical activity were selected for Study 2.

In Study 2, we conducted (a) an EFA with maximum likelihood (ML) estimation and oblimin rotation with all 46 barrier items and (b) a CFA with ML estimation using Mplus (EFA and CFA results are both interpreted by means of χ^2, CFI, RMSEA, and SRMR). Based on EFA results (n = 400), we selected 25 barrier items loading on seven discrete but related dimensions: *leisure activities* (meetings with peers, other favored weekend activities, and other favored hobbies), *lack of motivation* (not feeling like it, being too tired, and being too lazy), *screen-based sedentary behavior* (surfing the internet, watching TV, and playing computer games), *depressed mood* (feeling blue, mulling things over, and being in a bad mood), *physical health* (injury, illness, poor health), *school workload* (too much homework, long schooldays, and exam preparation), and *preconditions* (high costs, long distances to recreational facilities, and low perceived control over being physically active). Compared to one- to six-factor models, the seven-factor model was the first with an acceptable fit in all indices. Subsequently, this multidimensional model was tested with CFA (n = 198) also yielding acceptable fit indices. As indicated by Satorra-Bentler scaled χ^2 difference test, fit indices of a uni- and two-dimensional model were significantly worse than those of the multidimensional comparison model (Hypothesis 1). Criterion and discriminant validity were largely supported (Hypothesis 2 and 3). Leisure activities, lack of motivation, screen-based sedentary behavior, and school workload were the most impeding barriers to physical activity reported by adolescents.

Discussion and Conclusions

Based on results of the CFA, we combined adolescent-generated items to a multidimensional questionnaire. We showed that a measurement approach with several discrete dimensions of adolescents' barriers is valid within this sample and outperforms a uni- and two-dimensional approach. All seven barrier dimensions represent (a) age-specific developmental tasks (leisure activities: developing close peer relationships and a unique sense of identity including personal preferences; depressed mood: learning how to regulate increasingly complex and intense emotions; school workload: managing school obligations to graduate and prepare for the labor market), (b) age-specific competing interests (screen-based sedentary activities), and (c) common barriers, independent of age (lack of motivation, physical health and preconditions).

Since we focused exclusively on the degree to which barriers impede adolescents' physical activity, future studies should additionally examine how often barriers to physical activity are experienced to investigate the saliency of adolescents' barriers even better. To capture the complexity of adolescents' physical activity, self-reports should be complemented by accelerometers in future studies. Moreover, more adolescents with low physical activity levels should be encouraged to participate to examine more precisely whether physically inactive adolescents who want to become physically active experience more or qualitatively different barriers than physically active adolescents who struggle to stay physically active. Other validity criteria (e.g., action and coping self-efficacy, negative outcome experiences) should additionally be studied in future research to better examine the phase-specifity (pre- versus post-intentional) of barriers to physical activity.

In sum, the results of Study 1 and Study 2 are a valuable starting point for developing, improving, and evaluating targeted physical activity interventions (i.e., coping planning) to tackle those barriers to physical activity that are most important to adolescents. Given the mostly limited success of previous physical activity intervention programs, the development of physical activity barrier management strategies that are tailored to discrete barrier dimensions would be very promising. Using a comprehensive questionnaire of barriers to physical activity as a step within physical activity interventions may help adolescents to perceive not only those barriers that they already know but also to become aware of an even wider spectrum of their personal barriers to physical activity. In addition, this multidimensional questionnaire might also help health care providers to optimize their intervention strategies.

2.2 Summary for Manuscript II

Citation: Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2016). Physical Activity, Affect, and Cognition in Children with Symptoms of ADHD. *Journal of Attention Disorders, 20*, 151–162. doi:10.1177/1087054713493318
This manuscript includes two studies. I was only involved in Study 1.

Background and Objectives

There is some evidence that physical activity might alleviate adolescents' depressed affect. However, most previous studies used cross-sectional, longitudinal, or intervention designs that were not suitable for examining short-term changes of adolescents' physical activity and depressed affect within individuals. Instead, they rather studied differences in physical activity and depressed affect between individuals. Despite their valuable contributions for better understanding the mental health benefits of physical activity, these studies are not without limitations (e.g., excessive use of retrospective self-report measures of physical activity and retrospective ratings of depressed affect; focus on prescribed, structured, and supervised exercise). As one of very few studies, we aimed to investigate the association between self-initiated everyday physical activity, measured directly through pedometers, and adolescents' evening depressed affect within-person using an intensive longitudinal approach.

Adolescents at risk for or diagnosed with ADHD have a greater risk for comorbid mental problems such as depressed affect. In this target population, studies investigating the effects of increased physical activity on depressed affect are very limited. However, given the tendency of adolescents with higher levels of hyperactivity to also be more vulnerable to depressed affect than adolescents with lower levels of hyperactivity, the former are expected to benefit even more from more-than-usual physical activity.

We hypothesized (a) that adolescents showed less evening depressed affect on days with higher-than-usual physical activity (above the within-person mean) throughout the day (more-than-usual steps taken per day) than on days with less-than usual physical activity (significantly fewer-than-usual steps taken per day) and (b) that this within-person physical activity-depressed affect link would be stronger in adolescents with higher levels of hyperactivity.

Methods

We conducted an intensive longitudinal study with 38 young adolescents (age: *M* = 14.37, *SD* = 1.88 years; 47% males) with varying levels of hyperactivity (*M* = 0.63, *SD* = 0.59; scale range: 0-2). Participants wore a pedometer during waking hours (except during water-based activities) and completed evening diaries on depressed affect (either paper-and-pencil or online diaries, depending on their personal preference) over the course of 10 consecutive days. Physical activity was conceptualized as steps per day and measured through a widely used, valid pedometer. Adolescents' current evening depressed affect ("How do you feel right now?") was assessed through three items (sad, discouraged, and depressed; POMS, Cranford et al., 2006) using a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*extremely*). For each adolescent, we computed a mean depressed affect score for each evening. For reasons of sample description, depressive symptoms were assessed retrospectively based on the CES-D (Meyer & Hautzinger, 2001). With reference to the last 6 months, hyperactivity was assessed by means of a single screener item ("I constantly fidget or squirm") (self-report form, SDQ; Goodman, 1997) with a 3-point Likert scale ranging from 0 (*not true*) to 2 (*certainly true*). We analyzed the within-person physical activity-depressed affect link using mixed-effects models.

Results

Among all adolescents in our study, 16% showed elevated depressive symptoms (CES-D). On average, adolescents took 8,486 (*SD* = 4,941) steps per day, which is below the recommended level of 11,000-13,000 steps per day. Higher levels of hyperactivity were associated with more depressive symptoms (measured by CES-D). As expected, adolescents reported less evening depressed affect on days when they had taken more steps than usual per day (when compared to the within-person mean) than on days when they had taken fewer steps than usual per day. This within-person physical activity-depressed affect link was stronger in adolescents with higher levels of hyperactivity. Adolescents' evening depressed affect on a given day decreased with a 1-unit increase in physical activity (i.e., with each additional 10,000 steps per day) above the within-person mean to almost zero ("not at all"). We added baseline CES-D scores to the mixed-effects model which did not change the pattern of results. Thus, the stronger within-person link among adolescents with higher levels of hyperactivity was not due to their higher rate of depressive symptoms at baseline.

Discussion and Conclusions

Due to the very limited body of literature on this topic, the present study adds significantly to previous research. Consistent with our hypothesis, we showed that adolescents with more-than-usual physical activity on a given day experienced lower evening depressed affect; and this was particularly true for adolescents at risk for higher levels of hyperactivity.

Despite its valuable contributions for an underexplored area of physical activity research, this study has several limitations that refer to the study's design (no causal relationship could be examined), the sample size, the measurement of physical activity (no information on the intensity of physical activity), the measurement of depressed affect (frequent use of paper-and-pencil diaries without automatically generated time stamps), as well as the measurement of hyperactivity (use of a single hyperactivity item). Apart from these limitations, future studies should also examine (a) adolescents with the other two key symptoms of ADHD (i.e., inattentiveness and impulsivity) as well as adolescents with an ADHD diagnosis and (b) additional moderating and mediating mechanisms of the within-person link investigated in the current study. Moreover, future intensive longitudinal studies should increase measurement frequency of depressed affect to understand the temporal relations fluctuations in physical activity and depressed affect even better.

Provided that future studies replicate our results, physical activity might prove to be a cost-effective, low-threshold treatment option for adolescents, particularly for those at risk for higher levels of depressed affect and/or hyperactivity, which can be easily integrated into their daily routine. Compared to medication, physical activity has fewer side-effects and is less time-consuming than behavioral interventions, so that one day physical activity might complement or gradually replace the medical or behavioral interventions.

2.3 Summary for Manuscript III

Citation: Langguth, N., Schmid, J., Gawrilow, C., & Stadler, G. (2016). Within-Person Link between Depressed Affect and Moderate-to-Vigorous Physical Activity in Adolescence: An Intensive Longitudinal Approach. *Applied Psychology: Health and Well-Being, 8*, 44–63. doi:10.1111/aphw.12061

Background and Objectives

Particularly for young women, adolescence is a high-risk period for a sharp decrease in physical activity and a substantial increase in depressed affect. Low levels of physical activity and elevated depressed affect are both associated with severe physical and mental health problems in adolescents. For a long time, researchers have studied the between-person associations (i.e., interindividual differences) between physical activity (usually conceptualized as structured and supervised exercise; almost exclusive use of retrospective self-reported instead of direct measures such as pedometers or accelerometers) and depressed affect (usually conceptualized as a trait rather than a transient state; mostly retrospective ratings). Studying associations between persons (population level) enables researchers to answer the question whether adolescents who perform more physical activity on average show less depressed affect than adolescents who perform less physical activity. Overall, these cross-sectional, longitudinal, and intervention studies yielded small-to-moderate effect sizes. Intensive longitudinal studies, however, represent another research perspective (individual level) that aims to address the dynamic, short-term associations (i.e., change processes) between two states, in this case, everyday, self-initiated physical activity and depressed affect, using a prospective or real-time assessment approach with repeated measurements over time within real-world settings. Although intensive longitudinal designs have many advantages over more conventional designs, today, there are only three intensive longitudinal studies (two in children, one in adolescents) that investigated the within-person physical activity-depressed affect link, with mixed findings. The current study aimed to narrow this research gap.

Methods

We conducted an intensive longitudinal study with 72 adolescents (age: $M = 17.36$, $SD = 3.38$ years, mid-90% age range: 13-22; 63% males; 41% with an immigrant background) over nine consecutive days (seven weekdays, two weekend days). Participants wore an accelerometer during waking hours (except during water-based activities) and completed morning diaries (paper-and-pencil format) and evening diaries (either paper-and-pencil or online format, depending on participants' preference). We focused on moderate-to-vigorous physical activity (MVPA), because this intensity level is known to have the strongest impact on depressed affect. Adolescents' current depressed affect ("How do you feel right now?") was assessed with three items (sad, discouraged, and hopeless; POMS, Cranford et al., 2006) using a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*extremely*). For each adolescent, we mean a composite depressed affect score for each morning and each evening. We used mixed-effects models to analyze the within-person link between MVPA and next-morning (time-lagged prediction) and same-evening depressed affect (same-day link).

Results

Participants provided valid data for MVPA on 5.38 days (out of 7.00 possible days) with an average daily wear time of approximately 16.00 hours and for depressed affect on 6.75 mornings and 6.13 evenings, respectively (out of 7.00 possible entries each). Altogether, adolescents showed a high degree of commitment.

With regard to the time-lagged prediction, on weekdays (not on weekend days), more-than-usual MVPA predicted less next-morning depressed affect in young women (not in young men), to the extent that a 60-minute increase in MVPA over the within-person mean predicted 50% lower next-morning depressed affect. With respect to the same-day link, we found no association between MVPA and same-evening depressed affect at all. Diary format (i.e., paper-and-pencil versus online) did not moderate this link.

Discussion and Conclusions

Explanations for the weekdays versus weekend days effect might be due to (a) generally higher levels of physical activity on weekdays compared to weekdays (e.g., due to physical education classes and after-school physical activity), and (b) the small number of weekend days included in this study (i.e., insufficient power to detect a weekend day effect).

Explanations for the gender effect might refer to (a) possible differences in the type of physical activity between young women (e.g., preference for cooperative activities) and men (e.g., preference for competitive activities) that might have impact depressed affect differently, (b) possible differences in physical activity motives between young women (e.g., companionship) and young men (e.g., competition), (c) possible underlying mechanisms such as improved self-esteem and physical self-concept that should occur particularly in young women being commonly dissatisfied with their body shape during puberty, (d) possible differences in the dose-response relationship between physical activity and depressed (i.e., young women may require a lower dose of physical activity than young men to experience a decrease in depressed affect. Explanations for the missing same-day association may be due to (a) temporal dynamics between MVPA and depressed affect (i.e., short half-time of the antidepressant effect of physical activity on depressed affect) and (b) the impact of possible mediators such as sleep duration and quality.

Future intensive longitudinal studies should apply a multimethod approach for measuring adolescents' everyday physical activity and should assess depressed affect more frequently and solely through online or electronic diaries with automatically generated time stamps. Moreover, future research should additionally study moderating and mediating mechanisms of the within-person link found.

This is one of the very few studies that examined the within-person link between physical activity and depressed affect among adolescents by applying an intensive longitudinal approach. By doing so, we took an important step to better understand the temporal paths between adolescents' physical activity and depressed affect within person. This study encourages future replication studies as well as the development and improvement of tailored physical activity interventions. Enhancing adolescents' everyday physical activity appears beneficial especially for young women who have the highest risk for developing an inactive lifestyle and elevated depressed affect.

3. General Discussion

Based on Manuscripts I-III, this dissertation investigates barriers to adolescents' physical activity as well as the impact of adolescents' everyday physical activity on daily depressed affect. Taken together, results of Manuscripts I-III provide valuable insights into the content and dimensionality of adolescent-generated barriers to physical activity, which represent one of the most important correlates of physical activity, as well as the day-to-day association between adolescents' everyday physical activity and depressed affect within person, suggesting that young women and adolescents with higher levels of hyperactivity may particularly benefit. The main results of each manuscript are discussed in the following paragraphs. Subsequently, strengths and limitations of the studies will be described. Then, the most important implications due to theory building, methodology development, and practical application will be summarized. Finally, directions for future research will be outlined and main conclusions drawn.

3.1 Main Results from Manuscripts I–III

Barriers are a well-studied correlate of physical activity among adults. In adolescents, however, results are ambiguous for various reasons, such as lack of theoretical embedding and measurement issues. Until today, valid questionnaires for assessing barriers to physical activity relevant to adolescents are still missing. The major objectives of Manuscript I were (a) to identify the most salient barriers to adolescents' physical activity using a qualitative approach (Study 1), (b) to explore the dimensional structure of these adolescent-generated barriers, (c) to examine whether a multidimensional factor model would fit the data better than a uni- or two-dimensional approach, and (d) to develop a questionnaire on barriers to physical activity for adolescents and to test its psychometric properties (the latter points were examined in Study 2).

In Study 1 of Manuscript I, 118 adolescents generated a total of 602 barriers to physical activity (approximately five barriers per participant) that had kept them from physical activity during the previous week. Following the approach of Gyurcsik and colleagues (2006), two coders categorized 10% of the barriers and resolved disagreements by discussion (based on the current literature, preliminary categories comprised cognitive, emotional, motivational, physical, social, environmental, institutional physical barriers, lack of equipment and money, other prioritized leisure activities, and sedentary activities). Subsequently, each coder categorized the remaining 90% of barriers independently; interrater-reliability was almost perfect. Barriers were excluded if they were rarely mentioned, ambiguous, or too general (i.e., excuses rather than actual barriers) (Brawley at al., 1998). Finally, 46 barriers to physical activity most frequently cited by adolescents were selected for Study 2.

In Study 2 of Manuscript I, we conducted (a) an EFA with maximum likelihood (ML) estimation and oblimin rotation with all 46 barrier items and (b) a CFA with ML estimation using Mplus (EFA and CFA results are both interpreted by means of χ^2, CFI, RMSEA, and SRMR). To prevent over-factoring, criteria for EFA were as follows: (a) all factors should be represented by at least three significant items showing their highest loading on that factor and (b) all items of a factor should theoretically integrate to a plausible dimension. A seven-factor model (leisure activities, lack of motivation, screen-based sedentary behavior, depressed mood, physical health, school workload, and preconditions) containing 25 items was the first model with an acceptable fit (based on χ^2, CFI, RMSEA, and SRMR) that met the above mentioned two criteria. All eigenvalues were above 1; factor loadings ranged between .35 and .86. Based on the seven-factor model of the EFA, we conducted a CFA (the first loading of each factor was fixed at 1; all factors were allowed to correlate). All factors had meaningful variances; all standardized factor loadings were significant and > .48. Significant factor intercorrelations ranged between .24 (screen-based sedentary behavior and physical health) and .79 (leisure activities and lack of motivation), implying discrete but dependent dimensions. With respect to the high factor interrelation, we could show that combining the factors leisure activities and lack of motivation into one factor worsened the model fit considerably, implying that both factors cannot be subsumed to one. In another step, we showed that the fit of a unidimensional as well as a two-dimensional model were significantly worse than that of our seven-factor model as indicated by Satorra-Bentler scaled χ^2 difference test (Hypothesis 1, confirmed). Finally, we correlated our seven barrier factors with three variables that we assumed to be relevant to examine criterion validity. Results demonstrated that (a) particularly self-reported vigorous physical activity correlated negatively with all barrier factors, except physical health and preconditions, and (b) intention was negatively associated with all barrier factors, except physical health, preconditions, and school workload (Hypothesis 2, mainly confirmed). With respect to discriminant validity, self-efficacy was negatively related to all barrier factors, expect physical health and school workload, and negative outcome expectations correlated positively with all barrier dimensions (Hypothesis 3, mainly confirmed). In sum, results from Manuscript I revealed that measuring multiple, discrete barriers to adolescents' physical activity is a valid approach in this sample. Moreover, since all items were generated by adolescents themselves, besides criterion and discriminant validity, it can be reasonable assumed that the ecological validity of the present questionnaire is also supported. A more detailed discussion on the saliency of the derived dimensions and their relationship to adolescents' developmental tasks can be found in the discussion section of Manuscript I (Appendix A).

When aiming to examine day-to-day change processes occurring at the within-person level, intensive longitudinal designs are considered the method of choice. Studies investigating the within-person association between adolescents' physical activity and depressed affect are very rare. However, there have been no such studies to date which focus on adolescents who are more vulnerable to depressed affect such as adolescents with higher levels of hyperactivity. Therefore, Study 1 of Manuscript II aimed to contribute to closing this research gap. In this sample, higher levels of hyperactivity were related to higher levels of depressive symptoms at baseline (measured with the CES-D). Consistent with our hypothesis, results of Study 1 demonstrated that on days with more-than-usual physical activity (steps taken per day) throughout the day, adolescents showed less evening depressed affect than on days with less-than-usual physical activity. More precisely, on a given day, with each additional 10,000 steps taken per day, adolescents' depressed affect decreased to almost zero ("not at all"); this decrease was even greater among adolescents with higher levels of hyperactivity. The stronger association between physical activity and depressed affect among adolescents with higher levels of hyperactivity was not due to their higher levels of baseline depression. Due to the very limited body of literature, the present study adds significantly to the existing body of research. Naturally occurring (i.e., self-initiated, unstructured, and unsupervised) physical activity seems particularly suited for lowering depressed affect, particularly in those adolescents that have a higher risk for developing mental health problems. The discussion section of Study 1 in Manuscript II (Appendix B) provides a more detailed discussion based on the current literature.

Like Manuscript II, Manuscript III examined the within-person link between adolescents' physical activity and depressed affect—although with a different focus. Compared to Study 1 of Manuscript II, we aimed to improve the measurement methodology by quantifying adolescents' everyday physical activity through accelerometers (instead of pedometers) and assessing depressed affect twice a day in the morning and in the evening (instead of only once a day, that is, in the evening). We studied the moderating effects of gender and weekday versus weekend day (instead of hyperactivity). For young women (but not for young men) on weekdays (but not on weekend days), a 60-minute increase in MVPA over the within-person mean predicted 50% lower next-morning depressed affect. Contrary to our hypothesis, we found no same-day link between MVPA and evening depressed affect.

There are two main explanatory approaches for the weekday versus weekend day effect. First, on weekdays, adolescents were more physically active compared to weekend days, possibly due to more opportunities for physical activity on weekdays (e.g., physical education classes, after-school leisure physical activity). Second, since we only assessed adolescents' physical activity on one to two weekend days, the weekday effect was measured more precisely than the weekend day effect. With respect to the gender effect found, there are at least four possible explanations. First, since we were unable to measure context factors of adolescents' physical activity, such as the type of physical activity, we cannot confirm whether young women were in fact mostly engaged in cooperative activities whereas young men rather participated in competitive activities; however, performing cooperative or competitive activities might have influenced adolescents' depressed affect differently. Second, since young women in particular are commonly dissatisfied with their body shape during puberty, more-than-usual physical activity might have helped them to improve their self-esteem and physical self-concept and, thereby, to reduce their depressed affect. Third, differences in motives for physical activity (e.g., appearance, competition, or companionship) or motivational regulation (e.g., external or internal motivation) between young women and men might also have contributed to the gender effect found. Fourth, it might also be possible that young women required a lower dose of physical activity than young men to experience a decrease in depressed affect.

Possible explanations for the missing same-day link could be attributable to at least two aspects. First, on the same day, adolescents with more-than-usual physical activity might have experienced lower depressed affect only within a short time window; and this immediate effect might have already vanished after a few hours. That is, we cannot rule out that physical activity may have a short half-life due to other competing emotional experiences throughout the day or increasing fatigue. Second, it may also be possible that sleep serves as a mediator of the within-person physical activity-depressed affect link; more-than-usual physical activity throughout the day may improve adolescents' sleep quality or duration, which may, in turn, lead to lower depressed affect. A more in-depth discussion of the gender and weekday versus weekend effect and the lack of a same-day link can be found in the discussion section of Manuscript III.

3.2 Limitations and Strengths of Manuscripts I–III

Manuscript I has several limitations. First, in Study 2 of Manuscript I, the impact of barriers was only measured with respect to the extent of limitation. To capture the saliency of adolescents' barriers to physical activity even better and to further improve our understanding of how barriers impact adolescents' physical activity participation, in future studies, adolescents should be asked to additionally report the frequency with which specific barriers prevent them from being physically active within a particular time frame (Gyurcsik et al., 1998). In this context, researchers should bear in mind that some barriers may have a strong impact on adolescents' physical activity level but occur only on rare occasions (great limitation and low frequency; e.g., diseases) whereas other barriers may be less limiting but occur frequently (minor limitation and high frequency). Consequently, researchers should examine barriers in terms of both (a) frequency and (b) extent of limitation to determine the extent to which a particular barrier actually represents a problem that should be solved in a subsequent step. Second, in Study 2 of Manuscript I, adolescents were asked to respond to 25 barriers to physical activity with regard to the previous week; these items were generated by a comparable sample of adolescents in a prior study (Study 1 of Manuscript I). Although this time window appears to be quite short when compared to time reference periods applied by other researchers (e.g., "generally," Allison et al., 1999; De Bourdeaudhuij & Sallis, 2002; Krämer & Fuchs, 2010; "during the last six months," Gyurcsik et al., 2006), even shorter intervals should be used to further alleviate recall bias and heuristics use, thereby improving the validity of measurement. Third, since the current study had only one measuring point, we cannot draw conclusions about temporal or situational changes in adolescents' experience of barriers to physical activity, implying that barriers might also be regarded as state-like, transient, and time-varying constructs. Thus, it seems worthwhile to further investigate the immediate impact of particular barriers and distinct barrier dimensions, respectively, on adolescents' physical activity on a day-to-day or even hour-by-hour basis, using an intensive longitudinal approach. Fourth, since we measured physical activity exclusively through retrospective self-reports in Study 2, future studies should ideally quantify physical activity by applying a multi-method approach including accelerometers, daily diaries, and questionnaires as well as GPS data to gain more comprehensive information on the variety and complexity of adolescents' physical activity participation (e.g., duration, frequency, intensity, and type of physical activity, as well as information on the social and environmental context of adolescents' physical activity participation). By doing this, the reliability and validity of measurement would be enhanced. Fifth, since most of our participants were physically active, future research should also examine whether physically inactive adolescents who want to become active, experience more or different barriers, or whether they struggle with particular barriers more heavily than physically active adolescents who have a hard time maintaining physical active. This distinction has great practical importance since adolescents with varying levels of physical activity who want to be physically active might benefit from different barrier management strategies tailored to their individual requirements.

Despite these limitations, both studies of Manuscript I make several important contributions to the current literature. First, this is the first study that aims to develop a questionnaire for assessing barriers to adolescents' physical activity (Study 1) and evaluates its factor, criterion, and discriminant validity (Study 2). Second, since all these barriers were previously generated by adolescents in a comparable sample (Study 1), we studied diverse barriers to physical activity that are pertinent to our target population, thereby enhancing the ecological validity of results. Third, as opposed to prior studies, we followed both a qualitative and a qualitative approach; as a consequence, we ensured the saliency of barrier items to adolescents and enhanced the comparability of results across studies. Fourth, we studied two large samples of adolescents at different ages and from various social and ethnic backgrounds; in this way, we were able to improve the generalizability of results. Fifth, as opposed to many other researchers, we conducted CFA (instead of PCA) to evaluate the multidimensional structure of adolescents' barriers to physical activity. CFA is the only suitable method for explaining item interrelations and testing whether complex data fit a hypothesized model.

Study 1 of Manuscript II on hyperactivity as a moderator of the within-person physical activity-depressed affect association in adolescents is not without limitations. First, adolescents' hyperactivity was measured only once (i.e., at baseline) by means of a single item from a screening instrument for assessing adolescents' mental health, which was rated by adolescents. Therefore, in future studies it would be desirable (a) to assess adolescents' hyperactivity through more than a single item to enhance reliability of measurement and (b) to study adolescents' hyperactivity as a state variable, for example, on a daily or hourly basis to examine the dynamics between adolescents' hyperactivity, physical activity, and depressed affect more precisely. Second, since we investigated only adolescents from a non-clinical school sample, we cannot draw conclusions regarding adolescents diagnosed with ADHD. Third, as we only measured hyperactivity, it seems worthwhile to additionally examine whether adolescents who predominantly show the other two key symptoms of ADHD (i.e., inattentiveness and impulsivity) would benefit from physical activity in the same way as adolescents with higher levels of hyperactivity. Fourth, although there is evidence that diary data based on paper-and-pencil and online diaries are psychometrically and statistically equivalent (Green et al., 2006), we cannot rule out that adolescents who preferred paper-and-pencil diaries completed them earlier or later than agreed. Thus, to further enhance validity, future studies should administer online or electronic diaries whenever possible to ensure that adolescents complete their ratings on time. Fifth, the sample size was relatively small so that we could not examine additional moderation and mediation processes (e.g., impact of self-esteem). Thus, future studies should be designed with greater power to investigate these processes in detail. Sixth, as physical activity was only measured through pedometers, we lacked data on the type and context of physical activity (e.g., performing physical activity alone versus with others, cooperative versus competitive physical activity); thus, we were unable to investigate whether social aspects of physical activity interact with hyperactivity. Moreover, due to the use of pedometers, we cannot answer the question on whether varying physical activity intensity levels might impact adolescents' depressed affect differently, particularly in adolescents with higher levels of hyperactivity.

Study 1 of Manuscript II has several strengths. First, when Manuscript II was published, Study 1 was the only intensive longitudinal study that had examined the within-person association between physical activity and depressed affect among adolescents with varying levels of hyperactivity. Thus, this study was the first that investigated hyperactivity as a potential moderator of this within-person link. Second, we measured adolescents' everyday physical activity directly through pedometers. As opposed to self-report instruments of physical activity, pedometers are not likely to overestimate the amount of physical activity. Third, we used only items for assessing adolescents' depressed affect that had been previously tested to be reliable and valid for studying within-person change, primarily in adults (Cranford et al., 2006). In the present study, we additionally showed that these items are a reliable measure of day-to-day changes in depressed affect in adolescents.

Finally, the study described in Manuscript III has several limitations as well. First, we assessed adolescents' depressed affect only twice per day (i.e., on the next morning and the same evening). Therefore, we cannot draw conclusions about causality. However, this study can be regarded as a valuable starting point for future intensive longitudinal studies, which should investigate adolescents' depressed affect with a higher sampling frequency to better examine causal relations within person. Second, due to the applied measures, we could not study possible mediating mechanisms such as sleep quality or physical self-concept that might have led to the decrease in young women's next-morning depressed affect on weekdays. Third, in the morning, adolescents completed exclusively paper-and-pencil diaries to integrate their ratings of depressed affect more easily into their daily morning routine. Moreover, three-fourths of adolescents selected this format also for estimating their evening depressed affect. Thus, time stamps were only available for the few adolescents who decided to complete their evening diaries online. However, adolescents' accelerometer wear time (and thus their commitment) was generally very high, suggesting that adolescents might have been consistently reminded to complete their paper-and-pencil diaries whenever they attached and removed their accelerometer (in the morning and evening). In future studies, however, adolescents should fill out diaries exclusively online or electronically using computers or smartphones to better monitor the time of completion, thereby improving the validity of results. Fourth, since in the present study, we examined a maximum of two weekend days, we lacked the power to study the weekend effect more precisely. Thus, whenever feasible, future studies should extend the study period.

Despite these limitations, the current study makes substantial contributions to the very limited body of literature dedicated to this topic. First, this is, so far, the only study that has examined the within-person association between adolescents' everyday physical activity and their next-morning and same-evening depressed affect, which has thereby improved our understanding of the temporal relations between these two health determinants. Studying these within-person changes among adolescents is of great practical importance, since adolescence is a high risk period for physical inactivity (Kann et al., 2014) and elevated depressed affect (Thapar et al., 2012), leading to various short- and long-term negative consequences for adolescents' physical and mental health (Ekelund et al., 2012; Janssen & LeBlanc, 2010; Thapar et al., 2012; Verboom et al., 2014). Second, we used only items that had previously proved to be reliable and valid measures of the within-person change of depressed affect (Cranford et al., 2006). In the present study, we have shown that these items had also adequate within-person reliability for adolescents. Using measures that have been shown to reliably capture within-person change processes is essential (however, not self-evident) for studies following intensive longitudinal designs. Third, we measured physical activity directly through accelerometers—the gold standard of physical activity measurement; these monitors are not prone to overestimating the actual amount (i.e., duration, frequency, and intensity) of adolescents' physical activity (Corder et al., 2008). Moreover, we monitored physical activity for seven consecutive days (weekdays and weekend days) and analyzed only valid days with an accelerometer wear time of at least 600 minutes per day (Cain et al., 2013) to obtain reliable estimates of adolescents' habitual everyday physical activity. Fourth, in addition, we decided to study the entire spectrum of adolescents' self-initiated physical activity, thereby enhancing the ecological validity of our results.

3.3 Implications and Directions for Future Research from Manuscripts I–III

In the following, various implications of Manuscripts I-III for theory building, methodology development, and practical application as well as research objectives for future studies will be discussed in detail.

Manuscript I illustrated that a multidimensional approach is valid for measuring diverse barriers to physical activity among adolescents. Moreover, our model with several discrete barrier dimensions showed a better model fit than uni- and two-dimensional models. Based on our data, this implies that treating all barriers as equal (general factor model) or differentiating only between internal and external barriers is not appropriate for studying barriers to physical activity within our sample of adolescents. Study 2 of Manuscript I suggests that different intrapersonal barriers correlated with adolescents' physical activity differently. Thus, treating all intrapersonal barriers as equal (i.e., as a homogenous category) like in previous studies might no longer be appropriate. Instead, barriers to physical activity should be investigated as a multidimensional construct, with intrapersonal barriers being more diverse than previously expected. In Manuscript I, a qualitative study design was complemented by a quantitative approach, resulting in a validated questionnaire which contains exclusively adolescent-generated items that target those barriers to physical activity, which match the typical demands and developmental tasks of adolescents. Given that previous programs that aimed to improve adolescents' physical activity were of limited success (Bauman et al., 2012; Metcalf, Henley & Wilkin, 2012), Manuscript I provides evidence that future interventions should additionally focus on strategies that (a) are individually tailored to the most salient barriers and discrete barrier dimensions and (b) take possible developmental as well as individual variations regarding the experience of barriers to physical activity equally into account.

Furthermore, it would be very interesting to study whether single barriers or entire barrier categories change systematically during the transition from childhood to adolescence and young adulthood (mid-to-long-term changes). As developmental tasks change throughout life, priorities may also change—and so might barriers to physical activity. Moreover, it might also be valuable to investigate whether anticipated versus actual barriers impact adolescents' physical activity differently. This distinction might also be crucial for selecting the most appropriate intervention strategy (e.g., proactive versus reactive coping planning, Stadler & Hernandez, in preparation; Stadler, Wagner, Hernandez, & Gawrilow, in preparation) to help adolescents achieve their physical activity goals. Since physical activity is known to decrease among young women even more sharply than among young men (Hallal et al., 2012; Nader et al., 2008), studying the impact of gender on the experience of barriers to physical activity (frequency, type, and extent of limitation) seems also necessary for developing targeted barrier management strategies.

In sum, assessing diverse barriers to physical activity that represent adolescents' particular developmental stages and living conditions through valid questionnaires is essential for better understanding and promoting physical activity participation in this particular age group, given that adolescents are at high risk for developing an inactive lifestyle—given all of the negative consequences on their physical and mental health. Moreover, gaining deeper insight into the nature (i.e., diversity, frequency, and stability versus variability) of those barriers to physical activity most important to adolescents can bring us closer to answering the pressing question of why physical activity decreases during adolescence so substantially.

In Study 1 of Manuscript II, we showed that more-than-usual physical activity throughout the day was associated with lower evening depressed affect within person and that this association was stronger among adolescents with higher levels of hyperactivity. Symptoms of ADHD such as hyperactivity are commonly associated with other negative psychosocial outcomes such as low self-esteem, poor social skills, peer rejection, and anxious and depressed affect (Barkley et al., 2002; Murray-Close et al., 2010; Putukian et al., 2011). Thus, adolescents at risk for ADHD are also commonly at risk for comorbid mental problems. Studies with adolescents at risk for or diagnosed with ADHD that investigate the effects of physical activity on depressed affect are very rare. The results of Study 1 encourage future studies to examine whether promoting higher levels of physical activity is a promising strategy for self-regulating their depressed affect, especially for those adolescents at risk for ADHD and associated mental problems. Correspondingly, the current study shifts the scientific focus to a population that has been, so far, largely neglected when examining the benefits of physical activity on adolescents' mental health. Besides adolescents diagnosed with ADHD, adolescents with single ADHD symptoms or at greater risk of developing ADHD symptoms, should be ranked among the target group, as well. Since the items we used to quantify adolescents' depressed affect showed satisfactory reliability for measuring within-person change, these items are also available for future studies that aim to examine the within-person association between depressed affect and other variables of interest. In addition, there are several practical implications from the current study that should be considered. Provided that future studies replicate our results, physical activity may become a cost-effective treatment option for adolescents at risk for ADHD as well as depressed affect which can be easily integrated into their daily routine, and, therefore, can be maintained more easily in the long term, has fewer side-effects compared to medication, and is less time-consuming and burdensome than many behavioral interventions. For adolescents diagnosed with ADHD, physical activity might be an additional promising method of medical and behavioral treatment, respectively. While the latter treatments reduce exclusively ADHD symptoms, physical activity may also reduce comorbid symptoms, such as depressed affect. Moreover, future research should also study the context factors of physical activity, that is, "how," (leisure physical activity versus structured and organized sports programs) "where," (indoor versus outdoor, green spaces versus inner-city), and "with whom" (alone versus with others, cooperative versus competitive) adolescents should perform physical activity to alleviate their depressed affect as much as possible. In addition, the dose-response relationship also needs further investigation. As of yet, the optimal frequency (e.g., daily, 2-3 times per week), duration (acute versus chronic), and intensity (light, moderate, vigorous) of physical activity has not been specified. Another worthwhile research objective is to study the potential psychosocial and physiological mechanisms that may mediate the within-person link in the target group such as higher self-efficacy, improved social participation, better social skills, and increased synthesis of endorphins, dopamine, and serotonin.

Manuscript III contains many implications for future research on the within-person link between physical activity and depressed affect among adolescents. Previous cross-sectional and longitudinal studies, as well as randomized controlled trials, have mainly focused on the between-person association between physical activity and depressed affect among adolescents (i.e., interindividual differences). Due to the study design and the measures used, these studies have generally not been able to capture short-term change processes over time within individuals (within-person association; Kanning et al., 2013). As pointed out by Hamaker (2012), results at the between-person (i.e., population) level do not necessarily translate to those at the within-person (i.e., intraindividual) level. Since this is the only study, so far, that has investigated the within-person association between accelerometer-measured everyday physical activity and depressed affect from day to day and within the same day, it makes a substantial contribution to the very limited body of literature in this research area. We have shown that applying an intensive longitudinal design for school-based research on adolescents' physical activity and depressed affect is feasible. Thus, this study encourages future research to replicate our results and to further address the dynamics between physical activity and depressed affect among adolescents even more precisely by measuring depressed affect multiple times per day using smartphones, for example. Combining an intensive longitudinal approach with an intervention design (e.g., self-regulatory intervention to enhance physical activity) would also be a promising next step for studying causal relations. Moreover, our results indicate that future studies should carefully examine potential moderators, such as gender and day of the week (i.e., weekday versus weekend day), as well as additional moderators, to improve our understanding of the within-person link we have found. With regard to the measurement of physical activity, we decided against assessing physical activity context factors to keep participants' burden as low as possible. However, whenever possible, future studies should examine these context factors in order to identify other moderators and mediators to gain a deeper knowledge of the underlying processes. The results of the current study illustrate that the physical activity-depressed affect link is more complicated to study than previously suggested by cross-sectional studies, for example. As was the case with Study 1 of Manuscript II, items used in this study to measure depressed affect among adolescents showed adequate within-person reliability, and may, therefore, be applied to future studies, as well. Given that (a) the average daily depressed affect score of participants of the current study ranged from "not at all" to "a little," and (b) 25-30% of adolescents did not show any intraindividual variation of depressed affect across all study days, these items should be additionally tested in a sample of adolescents with higher levels and higher intraindividual variations of depressed affect (e.g., adolescents with mild-to-moderate depressive symptoms). The results of the current study also have great practical implications. If future research replicates this finding, higher everyday physical activity can serve (probably particularly for young women) as a cost-effective, feasible intervention strategy (a) for preventing higher levels of depressed affect for those at risk and (b) for alleviating depressed affect among those already diagnosed with mild-to-moderate depression. Thus, for adolescents diagnosed with depression, a prescription of regular physical activity could complement or even replace antidepressant medication. In this case, not only adolescents but also the health care system would benefit from such an intervention strategy. Moreover, targeted self-regulation strategies (e.g., Hynynen et al., 2016; Stadler, Oettingen, & Gollwitzer, 2009) show great potential for helping in particular those adolescents who have difficulty getting and staying physically active to increase their physical activity participation.

3.4 Conclusions from Manuscripts I–III

The newly developed questionnaire on adolescents' barriers to physical activity (Manuscript I) has a two-fold purpose. First, this questionnaire should help adolescents to identify not only those barriers to physical activity that they already know but also to become aware of an even wider spectrum of their personal barriers. Second, this questionnaire aims to provide health care providers with a useful, comprehensive means to improve interventions for physically inactive adolescents even further. Considering the substantial decrease in physical activity during adolescence, studying what actually impedes adolescents' physical activity participation is an important prerequisite for its promotion. Thus, the present questionnaire might provide the basis for future targeted, tailored interventions to sustainably enhance adolescents' physical activity.

Given that the decrease in physical activity during adolescence is associated with serious short-and long-term mental health problems, Manuscript II and III take up the issue and the purpose of Manuscript I and develop them further, by focusing on the antidepressant effects of physical activity. Both manuscripts show that more-than-usual unstructured everyday physical activity is associated with alleviated daily depressed affect among adolescents, particularly among young women and adolescents with higher levels of hyperactivity. These results suggest that physical activity may serve as a cost-effective, low-threshold intervention strategy, that might also be prescribed in the future, for reducing adolescents' daily depressed affect or for preventing it from turning into clinically relevant depression. Hence, from an individual as well as a social and economic viewpoint, helping adolescents to increase their everyday physical activity participation (e.g., through evidence-based interventions) shows great potential for promoting adolescents' mental health, for the present and the future.

4. References

Aaron, D. J., Storti, K. L., Robertson, R. J., Kriska, A. M., & LaPorte, R. E. (2002). Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: Implications for school curricula and community recreation programs. *Archives of Pediatrics and Adolescent Medicine, 156*, 1075–1080. doi:10.1001/archpedi.156.11.1075

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA school-age forms & profiles*. Burlington, VT: University of Vermont, Research Center for Children, Youth, and Families.

Adamo, K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S., & Tremblay, M. (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: A systematic review. *International Journal of Pediatric Obesity, 4*, 2–27. doi:10.1080/17477160802315010

Ainsworth, B. E., Haskell, W. L., Herrmann, S. D., Meckes, N., Bassett Jr, D. R., Tudor-Locke, C., ... & Leon, A. S. (2011). 2011 Compendium of physical activities: A second update of codes and MET values. *Medicine and Science in Sports and Exercise, 43*, 1575–1581. doi:10.1249/MSS.0b013e31821ece12

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckmann (Eds.), *Action-control: From cognition to behavior* (pp. 11–39). Heidelberg: Springer.

Allison, K. R., Dwyer, J. J. M., Goldenberg, E., & Fein, A. (2005). Male adolescents' reasons for participating in physical activity, barriers to participation, and suggestions for increasing participation. *Adolescence, 40*, 155–170.

Allison, K. R., Dwyer, J. J. M., & Makin, S. (1999). Perceived barriers to physical activity among high school students. *Preventive Medicine, 28*, 608–615. doi:10.1006/pmed.1999.0489

American College of Sports Medicine (2014). *ACSM's resource manual for guidelines for exercise testing and prescription* (7th ed.). Baltimore, MD: Lippincott Williams & Wilkins.

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). Washington, DC: American Psychiatric Association.

Annesi, J. J. (2005). Correlations of depression and total mood disturbance with physical activity and self-concept in preadolescents enrolled in an after-school exercise program. *Psychological Reports, 96*, 891–898. doi:10.2466/PR0.96.4.891-898

Armstrong, N., & Welsman, J. R. (2006). The physical activity patterns of European youth with reference to methods of assessment. *Sports Medicine, 36*, 1067–1086. doi:10.2165/ 00007256-200636120-00005

Atienza, A. A., Moser, R. P., Perna, F., Dodd, K., Ballard-Barbash, R., Troiano, R. P., & Berrigan, D. (2011). Self-reported and objectively measured activity related to bio-markers using NHANES. *Medicine and Science in Sports and Exercise, 43*, 815–821. doi:10.1249/MSS.0b013e3181fdfc32

Bandura, A. (1995, March). *Moving into forward gear in health promotion and disease prevention*. Keynote address presented at the Annual Meeting of the Society of Behavioral Medicine, San Diego.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education and Behavior, 31*, 143–164. doi:10.1177/1090198104263660

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urban (Eds.), *Self-efficacy beliefs of adolescents* (pp. 307–337). Greenwich, CT: Information Age Publishing.

Barkley, R. A. (2014a). Emotional dysregulation is a core component of ADHD. In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder: a handbook for diagnosis and treatment* (pp. 81–115). New York, NY: Guilford.

Barkley, R. A. (2014b). Concentration deficit disorder (sluggish cognitive tempo). In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder: a handbook for diagnosis and treatment* (pp. 435–454). New York, NY: Guilford.

Barkley, R. A., Cook, E. H., Diamond, A., Zametkin, A., Thapar, A., & Teeter, A. (2002). International consensus statement on ADHD. *Clinical Child and Family Psychology Review, 5*, 89–111. doi:10.1023/A:1017494719205

Bassett, D. R., Troiano, R. P., McClain, J. J., & Wolff, D. L. (2015). Accelerometer-based physical activity: Total volume per day and standardized measures. *Medicine and Science in Sports and Exercise, 47*, 833–838. doi:10.1249/MSS.0000000000000468

Batson, C. D., Shaw, L. L., & Oleson, K. C. (1992). Differentiating affect, mood, and emotion: Toward functionally based conceptual distinctions. In M. S. Clark (Ed.), *Review of personality and social psychology* (pp. 294–326). Newbury Park, CA: Sage.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., Martin, B. W., & Lancet Physical Activity Series Working Group (2012). Correlates of physical activity: Why are some people physically active and others not? *The Lancet, 380*, 258–271. doi:10.1016/S0140-6736(12)60735-1

References

Beffert, J. W. (1994). Aerobic exercise as treatment of depressive symptoms in early adolescents. *Dissertation Abstracts International, 54*(9-A), 3374.

Berger, B. G., Friedmann, E., & Eaton, M. (1988). Comparison of jogging, the relaxation response, and group interaction for stress reduction. *Journal of Sport and Exercise Psychology, 10*, 431–447.

Biddle, S. J. H., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine, 45*, 886–895. doi:10.1136/886 bjsports-2011-090185

Biddle, S. J. H., Atkin, A. J., Cavill, N., & Foster, C. (2011). Correlates of physical activity in youth: A review of quantitative systematic reviews. *International Review of Sport and Exercise Psychology, 4*, 25–49. doi:10.1080/1750984X.2010.548528

Biddle, S. J. H., Gorely, T., Pearson, N., & Bull, F. C. (2011). An assessment of self-reported physical activity instruments in young people for population surveillance: Project ALPHA. *International Journal of Behavioral Nutrition and Physical Activity, 8*:1. doi:10.1186/1479-5868-8-1

Biederman, J., Ball, S. W., Monuteaux, M. C., Mick, E., Spencer, T. J., McCreary, M., & Faraone, S. V. (2008). New insights into the comorbidity between ADHD and major depression in adolescent and young adult females. *Journal of the American Academy of Child and Adolescent Psychiatry, 47*, 426–434. doi:10.1097/CHI.0b013e31816429d3

Blackman, G. L., Ostrander, R., & Herman, K. C. (2005). Children with ADHD and depression: A multisource, multimethod assessment of clinical, social, and academic functioning. *Journal of Attention Disorders, 8*, 195–207. doi:10.1177/1087054705278777

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology, 54*, 579–616. doi:10.1038/nature02099

Bolger, N., & Laurenceau, J.-P. (Eds.). (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research*. New York, NY: Guilford.

Bonhauser, M., Fernandez, G., Püschel, K., Yañez, F., Montero, J., Thompson, B., & Coronado, G. (2005). Improving physical fitness and emotional well-being in adolescents of low socioeconomic status in Chile: Results of a school-based controlled trial. *Health Promotion International, 20*, 113–122. doi:10.1093/heapro/dah603

Bonomi, A. G., Goris, A. H., Yin, B., & Westerterp, K. R. (2009). Detection of type, duration, and intensity of physical activity using an accelerometer. *Medicine and Science in Sports and Exercise, 41*, 1770–1777. doi:10.1249/MSS.0b013e3181a24536

References

Brawley, L. R., Martin, K. A., & Gyurcsik, N. C. (1998). Problems in assessing perceived barriers to exercise: Confusing obstacles with attributions and excuses. In J. L. Duda (Ed.), *Advances in sport and exercise psychology measurement* (pp. 337–350). Morgantown, WV: Fitness Information Technology.

Brosnahan, J., Steffen, L. M., Lytle, L., Patterson, J., & Boostrom, A. (2004). The relation between physical activity and mental health among Hispanic and non-Hispanic white adolescents. *Archives of Pediatrics & Adolescent Medicine, 158*, 818–823. doi:10.1001/ archpedi.158.8.818

Brown, H. E., Pearson, N., Braithwaite, R. E., Brown, W. J., & Biddle, S. J. (2013). Physical activity interventions and depression in children and adolescents. *Sports Medicine, 43*, 195–206. doi:10.1007/s40279-012-0015-8

Burton, N. W., Khan, A., & Brown, W. J. (2012). How, where and with whom? Physical activity context preferences of three adult groups at risk of inactivity. *British Journal of Sports Medicine, 46*, 1125–1131. doi:10.1136/bjsports-2011-090554

Butte, N. F., Ekelund, U., & Westerterp, K. R. (2012). Assessing physical activity using wearable monitors: Measures of physical activity. *Medicine and Science in Sports and Exercise, 44*(Suppl. 1), S5–12. doi:10.1249/MSS.0b013e3182399c0e

Butte, N. F., Wong, W. W., Lee, J. S., Adolph, A. L., Puyau, M. R., & Zakeri, I. F. (2014). Prediction of energy expenditure and physical activity in preschoolers. *Medicine and Science in Sports and Exercise, 46*, 1216–1226. doi:10.1249/MSS.0000000000000209

Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoon, L. (2013). Using accelerometers in youth physical activity studies: A review of methods. *Journal of Physical Activity and Health, 10*, 437–450.

Carroll, S. L., Greig, C. A., Lewis, S. J., McMurdo, M. E., Sniehotta, F. F., Johnston, M., ... & Mead, G. E. (2012). The use of pedometers in stroke survivors: Are they feasible and how well do they detect steps? *Archives of Physical Medicine and Rehabilitation, 93*, 466–470. doi:10.1016/j.apmr.2011.08.047

Carson, V., & Spence, J. C. (2010). Seasonal variation in physical activity among children and adolescents: A review. *Pediatric Exercise Science, 22*, 81–92.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports, 100*, 126–131.

Chen, K. Y., & Bassett, D. R. (2005). The technology of accelerometry-based activity monitors: Current and future. *Medicine and Science in Sports and Exercise, 37*(Suppl. 11), S490–500. doi:10.1249/01.mss.0000185571.49104.82

Chinapaw, M. J., Mokkink, L. B., van Poppel, M. N., van Mechelen, W., & Terwee, C. B. (2010). Physical activity questionnaires for youth. *Sports Medicine, 40*, 539–563. doi:10.2165/11530770-000000000-00000

Chronis-Tuscano, A., Molina, B. S., Pelham, W. E., Applegate, B., Dahlke, A., Overmyer, M., & Lahey, B. B. (2010). Very early predictors of adolescent depression and suicide attempts in children with ADHD. *Archives of General Psychiatry, 67*, 1044–1051. doi:10.1001/archgenpsychiatry.2010.127

Clore, G. L., & Ortony, A. (2008). Appraisal theories: How cognition shapes affect into emotion. In M. Lewis, J. M. Haviland-Jones, & L. Feldman Barrett (Eds.), *Handbook of emotions* (pp. 628–642). New York, NY: Guilford.

Colley, R., Gorber, S. C., & Tremblay, M. S. (2010). Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Reports, 21*, 63–69.

Comte, M., Hobin, E., Majumdar, S. R., Plotnikoff, R. C., Ball, G. D. C., McGavock, J., & MIPASS and Healthy Hearts Investigators Teams (2013). Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Applied Physiology, Nutrition, and Metabolism, 38*, 115–119. doi:10.1139/apnm-2012-0100

Conners, C. K. (2008). *Conners 3rd edition manual*. North Tonawanda, NY: Multi-Health Systems Inc. (MHS).

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., & Brage, S. (2008). Assessment of physi-cal activity in youth. *Journal of Applied Physiology, 105*, 977–987. doi:10.1152/japplphysiol.00094.2008

Corder, K., Sharp, S. J., Atkin, A. J., Griffin, S. J., Jones, A. P., Ekelund, U., & van Sluijs, E. M. (2015). Change in objectively measured physical activity during the transition to adolescence. *British Journal of Sports Medicine*, *49*, 730–736. doi:10.1136/bjsports-2013-093190

Corder, K., van Sluijs, E. M., Wright, A., Whincup, P., Wareham, N., & Ekelund, U. (2009). Is it possible to assess free-living physical activity and energy expenditure in young people by self-report? *American Journal of Clinical Nutrition, 89*, 862–870. doi:10.3945/ajcn.2008.26739

Craig, C. L., Cameron, C., & Tudor-Locke, C. (2013). CANPLAY pedometer normative reference data for 21.271 children and 12.956 adolescents. *Medicine and Science in Sports and Exercise, 45*, 123–129. doi:10.1249/MSS.0b013e31826a0f3a

Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., … Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise, 35*, 1381–1395. doi:10.1249/ 01.MSS.0000078924.61453.FB

Cranford, J. A., Shrout, P. E., Iida, M., Rafaeli, E., Yip, T., & Bolger, N. (2006). A procedure for evaluating sensitivity to within-person change: Can affect measures in diary studies detect change reliably? *Personality and Social Psychology Bulletin, 32*, 917–929. doi:10.1177/0146167206287721

Curran, S. L., Andrykowski, M. A., & Studts, J. L. (1995). Short form of the Profile of Mood States (POMS-SF): Psychometric Information. *Psychological Assessment, 7*, 80–83. doi:10.1037/1040-3590.7.1.80

Daley, A. J., Copeland, R. J., Wright, N. P., Roalfe, A., & Wales, J. K. (2006). Exercise therapy as a treatment for psychopathologic conditions in obese and morbidly obese adolescents: A randomized, controlled trial. *Pediatrics, 118*, 2126–2134. doi:10.1542/peds.2006-1285

Daviss, W. (2008). A review of co-morbid depression in pediatric ADHD: Etiologies, phenome-nology, and treatment. *Journal of Child and Adolescent Psychopharmacology, 18*, 565–571. doi:10.1089/cap.2008.032

De Bourdeaudhuij, I., & Sallis, J. F. (2002). Relative contribution of psychosocial variables to the explanation of physical activity in three population-based adult samples. *Preventive Medicine, 34*, 279–288. doi:10.1006/pmed.2001.0979

De Vries, S., Van Hirtum, H., Bakker, I., Hopman-Rock, M., Hirasing, R., & van Mechelen, W. (2009). Validity and reproducibility of motion sensors in youth. *Medicine and Science in Sports and Exercise, 41*, 818–827. doi:10.1249/MSS.0b013e31818e5819

Dishman, R. K. (Ed.). (1988). *Exercise adherence: It's impact on public health.* Champaign, IL: Human Kinetics.

Dreher, E., & Dreher, M. (1985). Entwicklungsaufgaben im Jugendalter: Bedeutsamkeit und Bewältigungskonzepte [Developmental tasks in adolescence: Meaning and coping con-cepts]. In D. Liepmann & A. Stiksrud (Eds.), *Entwicklungsaufgaben und Bewältigungs-probleme in der Adoleszenz* [Developmental tasks and coping problems in adolescence] (pp. 56–70). Göttingen, Germany: Hogrefe.

Duckham, R. L., Baxter-Jones, A. D. G., Johnston, J. D., Vatanparast, H., Cooper, D., & Kontulainen, S. (2014). Does physical activity in adolescence have site-specific and sex-specific benefits on young adult bone size, content, and estimated strength? *Journal of Bone and Mineral Research, 29*, 479–486. doi:10.1002/jbmr.2055

Dumith, S. C., Gigante D. P., Domingues, M. R., Hallal, P. C., Menezes, A. M. B., & Kohl, H. W. (2012) A longitudinal evaluation of physical activity in Brazilian adolescents: Tracking, change and predictors. *Pediatric Exercise Science, 24*, 58–71.

Dumith, S. C., Gigante, D. P., Domingues, M. R., & Kohl, H. W. (2011). Physical activity change during adolescence: A systematic review and a pooled analysis. *International Journal of Epidemiology, 40*, 685–698. doi:10.1093/ije/dyq272

Dunton, G. F., Huh, J., Leventhal, A. M., Riggs, N., Hedeker, D., Spruijt-Metz, D., & Pentz, M. A. (2014). Momentary assessment of affect, physical feeling states, and physical activity in children. *Health Psychology, 33*, 255–263. doi:10.1037/a0032640

Ebner-Priemer, U. W., & Trull, T. J. (2009). Ecological momentary assessment of mood disorders and mood dysregulation. *Psychological Assessment, 21*, 463–475. doi:10.1037/a0017075

Ekelund, U., Luan, J., Sherar, L. B., Esliger, D. W., Griew, P., Cooper, A., & the International Children's Accelerometry Database (ICAD) Collaborators (2012). Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and ado- lescents. *The Journal of the American Medical Association, 307*, 704–712. doi:10.1001/ jama.2012.156

Ekkekakis, P. (2012). The measurement of affect, mood, and emotion in exercise psychology. In G. Tenenbaum, R. C. Eklund, & A. Kamata (Eds.), *Measurement in sport and exercise psychology* (pp. 321–332). Champaign, IL: Human Kinetics.

Ekkekakis, P. (2013). *The measurement of affect, mood, and emotion: A guide for health-behavioral research*. Cambridge, UK: University Press.

Ekkekakis, P., & Petruzzello, S. J. (2000). Analysis of the affect measurement conundrum in exercise psychology: I. Fundamental issues. *Psychology of Sport and Exercise, 1*, 71–88. doi:10.1016/S1469-0292(00)00010-8

Ekkekakis, P., & Petruzzello, S. J. (2002). Analysis of the affect measurement conundrum in exercise psychology: IV. A conceptual case for the affect circumplex. *Psychology of Sport and Exercise, 3*, 35–63. doi:10.1016/S1469-0292(01)00028-0

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion*, *6*, 169–200. doi:10.1080/02699939208411068

Ellery, C. V. L., Weiler, H. A., & Hazell, T. J. (2014). Physical activity assessment tools for use in overweight and obese children. *International Journal of Obesity, 38*, 1–10. doi:10.1038/ijo.2013.125

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences, 26*, 1557–1565. doi:10.1080/02640410802334196

Faraone, S. V., Biederman, J., & Mick, E. (2006). The age-dependent decline of attention deficit hyperactivity disorder: A meta-analysis of follow-up studies. *Psychological Medicine, 36*, 159–165. doi:10.1017/S003329170500471X

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Medicine and Science in Sports and Exercise, 37*(Suppl. 11), S523–530. doi:10.1249/ 01.mss.0000185658.28284.ba

Gapin, J. I., & Etnier, J. L. (2008). Relationship between physical activity, behavioral symptoms, and executive function in ADHD children. *Journal of Sport and Exercise Psychology, 30*, S25.

Gapin, J. I., & Etnier, J. L. (2010). The relationship between physical activity and executive function performance in children with attention-deficit hyperactivity disorder. *Journal of Sport and Exercise Psychology, 32*, 753–763.

Gapin, J. I., Labban, J. D., & Etnier, J. L. (2011). The effects of physical activity on attention deficit hyperactivity disorder symptoms: The evidence. *Preventive Medicine, 52*(Suppl. 1), S70–74. doi:10.1016/j.ypmed.2011.01.022

Garcia, A. W., Broda, M. A. N., Frenn, M., Coviak, C., Pender, N. J., & Ronis, D. L. (1995). Gender and developmental differences in exercise beliefs among youth and prediction of their exercise behavior. *Journal of School Health, 65*, 213–219. doi:10.1111/j.1746-1561.1995.tb03365.x

Gauvin, L., Rejeski, W. J., & Norris, J. L. (1996). A naturalistic study of the impact of acute physical activity on feeling states and affect in women. *Health Psychology, 15*, 391–397. doi:10.1037/0278-6133.15.5.391

Gawrilow, C., Kühnhausen, J., Schmid, J., & Stadler, G. (2014). Hyperactivity and motoric activity in ADHD: Characterization, assessment, and intervention. *Frontiers in Psychiatry, 5*:71. doi:10.3389/fpsyt.2014.00171

Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2016). Physical activity, affect, and cognition in children with symptoms of ADHD. *Journal of Attention Disorders, 20*, 151–162. doi:10.1177/1087054713493318

Giannakidou, D. M., Kambas, A., Ageloussis, N., Fatouros, I., Christoforidis, C., Venetsanou, F., & Taxildaris, K. (2012). The validity of two Omron pedometers during treadmill walking is speed dependent. *European Journal of Applied Physiology, 112*, 49–57. doi:10.1007/s00421-011-1951-y

Godin, G., Desharnais, R., Valois, P., Lepage, L., Jobin, J., & Bradet, R. (1994). Differences in perceived barriers to exercise between high and low intenders: Observations among different populations. *American Journal of Health Promotion, 8*, 279–285. doi:10.4278/0890-1171-8.4.279

Goldfield, G. S., Mallory, R., Parker, T., Cunningham, T., Legg, C., Lumb, A., ... & Adamo, K. B. (2007). Effects of modifying physical activity and sedentary behavior on psychosocial adjustment in overweight/obese children. *Journal of Pediatric Psychology, 32*, 783–793. doi:10.1093/jpepsy/jsm017

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A research note. *Journal of Child Psychology & Psychiatry, 38*, 581–586. doi:10.1111/j.1469-7610.1997.tb01545.x

Goodman, R., & Scott, S. (1999). Comparing the Strengths and Difficulties Questionnaire and the Child Behavior Checklist: Is small beautiful? *Journal of Abnormal Child Psychology, 27*, 17–24. doi:10.1023/A:1022658222914

Goodrich, F. G. (1984). The effects of aerobic fitness training on hostility and depression in a college population. *Dissertation Abstracts International, 45*(6-B), Dec–B.

Gray, E. K., & Watson, D. (2007). Assessing positive and negative affect via self-report. In J. A. Coan & J. J. B. Allen (Eds.), *Handbook of emotion elicitation and assessment* (pp. 171–183). New York, NY: Oxford University Press.

Green, L. W., Richard, L., & Potvin, L. (1996). Ecological foundations of health promotion. *American Journal of Health Promotion, 10*, 270–281. doi:10.4278/0890-1171-10.4.270

Gross, J. J., & Thompson, R. A. (2010). Emotion regulation: Conceptual foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 135–158). New York, NY: Guilford.

Guidelines for the data processing and analysis of the International Physical Activity Questionnaire (IPAQ) - short and long forms contents (2005). Retrieved from: http://www.academia.edu/5346814/Guidelines_for_Data_Processing_and_Analysis_of_the_International_Physical_Activity_Questionnaire_IPAQ_Short_and_Long_Forms_Contents

Gyurcsik, N. C., Bray, S. R., & Brittain, D. R. (2004). Coping with barriers to vigorous physical activity during transition to university. *Family & Community Health, 27*, 130–142. doi:10.1097/00003727-200404000-00006

Gyurcsik, N. C., Spink, K. S., Bray, S. R., Chad, K., & Kwan, M. (2006). An ecologically based examination of barriers to physical activity in students from grade seven through first-year university. *Journal of Adolescent Health, 38*, 704–711. doi:10.1016/j.jadohealth.2005.06.007

Haarasilta, L. M., Marttunen, M. J., Kaprio, J. A., & Aro, H. M. (2004). Correlates of depression in a representative nationwide sample of adolescents (15–19 years) and young adults (20–24 years). *The European Journal of Public Health, 14*, 280–285. doi:10.1093/eurpub/14.3.280

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., & the Lancet Physical Activity Series Working Group (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *The Lancet, 380*, 247–257. doi:10.1016/S0140-6736(12)60646-1

Hallal, P. C., & Lee, I.-M. (2013). Prescription of physical activity: An undervalued intervention. *The Lancet, 381*, 356–357. doi:10.1016/S0140-6736(12)61804-2

Hamaker, E.L. (2012). Why researchers should think "within-person": A paradigmatic rationale. In M. R. Mehl & T. S. Conner (Eds.), *Handbook of research methods for studying daily life* (pp. 43–61). New York: Guilford.

Hands, B., Parker, H., Glasson, C., Brinkman, S., & Read, H. (2004). *Physical activity and nutrition levels in Western Australian children and adolescents: Report*. Perth, Western Australia: Western Australian Government.

Havighurst, R. J. (1948). Developmental task and education. Chicago, IL: University of Chicago.

Hilyer, J. C., Wilson, D. G., Dillon, C., Caro, L., Jenkins, C., Spencer, W. A., ... & Booker, W. (1982). Physical fitness training and counseling as treatment for youthful offenders. *Journal of Counseling Psychology, 29*, 292–303. doi:10.1037/0022-0167.29.3.292

Hume, C., Timperio, A., Veitch, J., Salmon, J., Crawford, D., & Ball, K. (2011). Physical activity, sedentary behavior, and depressive symptoms among adolescents. *Journal of Physical Activity and Health, 8*, 152–156.

Hynynen, S. T., van Stralen, M. M., Sniehotta, F. F., Araújo-Soares, V., Hardeman, W., Chinapaw, M. J. M., ... & Hankonen, N. (2016). A systematic review of school-based interventions targeting physical activity and sedentary behaviour among older adolescents. *International Review of Sport and Exercise Psychology, 9*, 22–44. doi:10.1080/1750984X.2015.1081706

Imeraj, L., Antrop, I., Roeyers, H., Deboutte, D., Deschepper, E., Bal, S., & Sonuga-Barke, E. (2016). The impact of idle time in the classroom: Differential effects on children with ADHD. *Journal of Attention Disorders, 20*, 71–81. doi:10.1177/1087054713478464

Izard, C. E. (1993). Organizational and motivational functions of discrete emotions. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 631–641). New York, NY: Guilford.

Jackson, E. L. (1988). Leisure constraints: A survey of past research. *Leisure Science, 10*, 203–215. doi:10.1080/01490408809512190

Janssen, I., & LeBlanc, A. G. (2010). Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*:40. doi:10.1186/1479-5868-7-40

Janz, K. F., Letuchy, E. M., Burns, T. L., Gilmore, J. M. E., Torner, J. C., & Levy, S. M. (2014). Objectively measured physical activity trajectories predict adolescent bone strength: Iowa Bone Development Study. *British Journal of Sports Medicine, 48*, 1032–1036. doi:10.1136/bjsports-2014-093574

Janz, N. K., & Becker, M. H. (1984). The health belief model: A decade later. *Health Education Quarterly, 11*, 1–47. doi:10.1177/109019818401100101

Jekauc, D., Reimers, A. K., Wagner, M. O., & Woll, A. (2012). Prevalence and socio-demographic correlates of the compliance with the physical activity guidelines in children and adolescents in Germany. *BMC Public Health, 12*:714. doi:10.1186/1471-2458-12-714

Jensen, P. S., & Kenny, D. T. (2004). The effects of yoga on the attention and behavior of boys with attention-deficit/hyperactivity disorder (ADHD). *Journal of Attention Disorders, 7*, 205–216. doi:10.1177/108705470400700403

Jerstad, S. J., Boutelle, K. N., Ness, K. K., & Stice, E. (2010). Prospective reciprocal relations between physical activity and depression in female adolescents. *Journal of Consulting and Clinical Psychology, 78*, 268–272. doi:10.1037/a0018793

John, D., & Freedson, P. (2012). ActiGraph and Actical physical activity monitors: A peek under the hood. *Medicine and Science in Sports and Exercise, 44*(Suppl. 1), S86–89. doi:10.1249/MSS.0b013e3182399f5e

Kann, L., Kinchen, S., Shanklin, S. L., Flint, K. H., Kawkins, J., Harris, W. A., ... & Zaza, S. (2014). Youth risk behavior surveillance—United States, 2013. *Morbidity and Mortality Weekly Report Surveillance Summaries, 63*(Suppl. 4), S1–168.

Kanning, M. K., Ebner-Priemer, U. W., & Schlicht, W. M. (2013). How to investigate within-subject associations between physical activity and momentary affective states in everyday life: A position statement based on a literature overview. *Frontiers in Psychology, 4*:187. doi:10.3389/fpsyg.2013.00187

Kiluk, B. D., Weden, S., & Culotta, V. P. (2009). Sport participation and anxiety in children with ADHD. *Journal of Attention Disorders, 12*, 499–506. doi:10.1177/1087054708320400

Kjønniksen, L., Torsheim, T., & Wold, B. (2008). Tracking of leisure-time physical activity during adolescence and young adulthood: A 10-year longitudinal study. *International Journal of Behavioral Nutrition and Physical Activity, 5*:69. doi:10.1186/1479-5868-5-69

Klasen, H., Woerner, W., Wolke, D., Meyer, R., Overmeyer, S., Kaschnitz, W., … Goodman, R. (2000). Comparing the German versions of the Strengths and Difficulties Questionnaire (SDQ-Deu) and the Child Behavior Checklist. *European Child and Adolescent Psychiatry, 9*, 271–276. doi:10.1007/s007870070030

Krämer, L. (2014). Barrieren, gesundheitsbezogene [Barriers, health-related]. In M. A. Wirtz (Ed.), *Dorsch - Lexikon der Psychologie* (p. 238). Bern, Switzerland: Huber.

Krämer, L. & Fuchs, R. (2010). Barrieren und Barrierenmanagement im Prozess der Sportteilnahme: Zwei neue Messinstrumente [Barriers and barrier management in physical exercise: Introduction of two new assessment instruments]. *Zeitschrift für Gesundheitspsychologie, 18*, 170–182. doi:10.1026/0943-8149/a000026

Kühnhausen, J., Leonhardt, A., Dirk, J., & Schmiedek, F. (2013). Physical activity and affect in elementary school children's daily lives. *Frontiers in Psychology, 4*:456. doi:10.3389/ fpsyg.2013.00456

Lane, A. M., & Lane, H. J. (2002). Predictive effectiveness of mood measures. *Perceptual and Motor Skills, 94*, 785–791. doi:10.2466/pms.2002.94.3.785

Larsen, R. J. (2000). Toward a science of mood regulation. *Psychological Inquiry, 11*, 129–141. doi:10.1207/S15327965PLI1103_01

Larsen, R. J., & Diener, E. (1992). Promises and problems with the circumplex model of emotion. In M. S. Clark (Ed.), *Emotion* (pp. 25–59). Newbury Park, CA: Sage.

Larun, L., Nordheim, L., Ekeland, E., Hagen, K. B., & Heian, F. (2006). Exercise in prevention and treatment of anxiety and depression among children and young people. *Cochrane Database of Systematic Reviews, 3*:CD004691. doi:10.1002/14651858.CD004691.pub2

Lazarus, R.S. (1991). Cognition and motivation in emotion. *American Psychologist, 46*, 352–367. doi:10.1037/0003-066X.46.4.352

Lee, P. H., Macfarlane, D. J., Lam, T. H., & Stuart, S. M. (2011). Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8*:115. doi:10.1186/1479-5868-8-115

LePage, M. L., & Crowther, J. H. (2010). The effects of exercise on body satisfaction and affect. *Body Image, 7*, 124–130. doi:10.1016/j.bodyim.2009.12.002

Liao, Y., Shonkoff, E. T., & Dunton, G. F. (2015). The acute relationships between affect, physical feeling states, and physical activity in daily life: A review of current evidence. *Frontiers in Psychology, 6*:1975. doi:10.3389/fpsyg.2015.01975

Lorr, M., Shi, A. Q., & Youniss, R. P. (1989). A bipolar multifactor conception of mood states. *Personality and Individual Differences, 10*, 155–159. doi:10.1016/0191-8869(89)90199-2

MacMahon, J. R., & Gross, R. T. (1988). Physical and psychological effects of aerobic exercise in delinquent adolescent males. *American Journal of Diseases of Children, 142*, 1361–1366.

Mammen, G., & Faulkner, G. (2013). Physical activity and the prevention of depression: A systematic review of prospective studies. *American Journal of Preventive Medicine, 45*, 649–657. doi:10.1016/j.amepre.2013.08.001

Mata, J., Thompson, R. J., Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Gotlib, I. H. (2012). Walk on the bright side: Physical activity and affect in major depressive disorder. *Journal of Abnormal Psychology, 121*, 297–308. doi:10.1037/a0023533

Mattocks, C., Ness, A. R., Leary, S. D., Tilling, K., Blair, S. N., Shield, J., ... & Riddoch, C. J. (2008). Use of accelerometers in a large field-based study of children: Protocols, design issues, and effects on precision. *Journal of Physical Activity and Health, 5*(Suppl. 1), S98–111.

McAuley, E. (1994). Physical activity and psychosocial outcomes. In C. B. Bouchard, R. J. Shepard, & T. Stephens (Eds.), *Physical activity, fitness, and health* (pp.551–568). Champaign, IL: Human Kinetics.

McClain, J. J., Abraham, T. L., Brusseau Jr, T. A., & Tudor-Locke, C. (2008). Epoch length and accelerometer outputs in children: Comparison to direct observation. *Medicine and Science in Sports and Exercise, 40*, 2080–2087. doi:10.1249/MSS.0b013e3181824d98

McLeroy, K. R., Bibeau, D., Steckler, A., & Glanz, K. (1988). An ecological perspective on health promotion programs. *Health Education & Behavior 15*, 351–377. doi:10.1177/109019818801500401

McNair, D. M., & Lorr, M. (1964). An analysis of mood in neurotics. *The Journal of Abnormal and Social Psychology, 69*, 620–627.

McNair, D. M., Lorr, M., & Droppleman, L. F. (1971). *Profile of Mood States (POMS) manual*. San Diego, CA: Educational and Industrial Testing Service.

Medina, J. A., Netto, L. B., Muszkat, M., Medina, A. C., Botter, D., Orbetelli, R., & Miranda, M. C. (2010). Exercise impact on sustained attention of ADHD children, methylphenidate effects. *Attention Deficit Hyperactivity Disorders, 2*, 49–58. doi:10.1007/s12402-009-0018-y

Melnyk, B. M., Jacobson, D., Kelly, S., O'Haver, J., Small, L., & Mays, M. Z. (2009). Improving the mental health, healthy lifestyle choices, and physical health of Hispanic adolescents: A randomized controlled pilot study. *Journal of School Health, 79*, 575–584. doi:10.1111/j.1746-1561.2009.00451.x

Mendelson, T., Greenberg, M. T., Dariotis, J. K., Gould, L. F., Rhoades, B. L., & Leaf, P. J. (2010). Feasibility and preliminary outcomes of a school-based mindfulness intervention for urban youth. *Journal of Abnormal Child Psychology, 38*, 985–994. doi:10.1007/ s10802-010-9418-x

Metcalf, B., Henley, W., & Wilkin, T. (2012). Effectiveness of intervention on physical activity of children: Systematic review and meta-analysis of controlled trials with objectively measured outcomes. *British Medical Journal, 345*:e5888.

Montoye, A. H., Pfeiffer, K. A., Suton, D., & Trost, S. G. (2014). Evaluating the responsiveness of accelerometry to detect change in physical activity. *Measurement in Physical Education and Exercise Science, 18*, 273–285. doi:10.1080/1091367X.2014.942454

Morris, W. N. (1992). A functional analysis of the role of mood in affective systems. In M. S. Clark (Ed.), *Review of personality and social psychology* (pp. 256–293). Newbury Park, CA: Sage.

Murphy, S. L. (2009). Review of physical activity measurement using accelerometers in older adults: Considerations for research design and conduct. *Preventive Medicine, 48*, 108–114. doi:10.1016/j.ypmed.2008.12.001

Murray-Close, D., Hoza, B., Hinshaw, S. P., Arnold, L. E., Swanson, J., Jensen, P. S., & Wells, K. (2010). Developmental processes in peer problems of children with ADHD in the MTA Study: Developmental cascades and vicious cycles. *Development and Psychopathology, 22*, 785–802. doi:10.1017/S0954579410000465

Nader, P. R., Bradley, R. H., McRitchie, S. L., Houts, R. M., & O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *Journal of the American Medical Association, 300*, 295–305. doi:10.1001/jama.300.3.295

Neudecker, C., Mewes, N., Reimers, A. K., & Woll, A. (2015). Exercise Interventions in Children and Adolescents With ADHD: A Systematic Review. *Journal of Attention Disorders*. Advance online publication. doi:10.1177/1087054715584053

Newton, K. H., Wiltshire, E. J., & Elley, C. R. (2009). Pedometers and text messaging to increase physical activity randomized controlled trial of adolescents with type 1 diabetes. *Diabetes Care, 32*, 813–815. doi:10.2337/dc08-1974

Norris, R., Carroll, D., & Cochrane, R. (1992). The effects of physical activity and exercise training on psychological stress and well-being in an adolescent population. *Journal of Psychosomatic Research, 36*, 55–65. doi:10.1016/0022-3999(92)90114-H

Nowlis, V., & Nowlis, H. H. (1956). The description and analysis of mood. *Annals of the New York Academy of Sciences, 65*, 345–355. doi:10.1111/j.1749-6632.1956.tb49644.x

O'Dea, J. A. (2003). Why do kids eat healthful food? Perceived benefits of and barriers to healthful eating and physical activity among children and adolescents. *Journal of the American Dietetic Association, 103*, 497–501. doi:10.1016/S0002-8223(03)00013-0

Ortega, F. B., Konstabel, K., Pasquali, E., Ruiz, J. R., Hurtig-Wennlöf, A., Mäestu, J., ... & Sjöström, M. (2013). Objectively measured physical activity and sedentary time during childhood, adolescence and young adulthood: A cohort study. *PLoS One, 8*(4):e60871. doi:10.1371/journal.pone.0060871

Osgood, C. E., Suci, G. J., & Tannenbaum, P. H. (1957). *The measurement of meaning*. Urbana, IL: University of Illinois Press.

Pate, R. R., O'Neill, J. R., & Lobelo, P. (2008). The evolving definition of "sedentary". *Exercise and Sport Sciences Reviews, 36*, 173–178. doi:10.1097/JES.0b013e3181877d1a

Pate, R. R., Saunders, R. P., O'Neill, J. R., & Dowda, M. (2011). Overcoming barriers to physical activity: Helping youth be more active. *ACSM's Health & Fitness Journal, 15*, 7–12. doi:10.1249/FIT.0b013e318201c8ee

Payne, R. (2001). Measuring emotions at work. In R. L. Payne & C. L. Cooper (Eds.), *Emotions at work: Theory, research and applications for management* (pp. 107–129). West Sussex, UK: Wiley & Sons Ltd.

Pescatello, L. S., Arena, R., Riebe, D., & Thompson, P. D. (Eds.). (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Petty, K. H., Davis, C. L., Tkacz, J., Young-Hyman, D., & Waller, J. L. (2009). Exercise effects on depressive symptoms and self-worth in overweight children: A randomized controlled trial. *Journal of Pediatric Psychology, 34*, 929–939. doi:10.1093/jpepsy/jsp007

Pliszka, S., & AACAP Work Group on Quality Issues. (2007). Practice parameter for the assessment and treatment of children and adolescents with attention-deficit/hyperactivety disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 46*, 894–921. doi:10.1097/chi.0b013e318054e724

Pober, D. M., Staudenmayer, J., Raphael, C., & Freedson, P. S. (2006). Development of novel techniques to classify physical activity mode using accelerometers. *Medicine and Science in Sports and Exercise, 38*, 1626–1634. doi:0.1249/01.mss.0000227542.43669.45

Pontifex, M. B., Saliba, B. J., Raine, L. B., Picchietti, D. L., & Hillman, C. H. (2013). Exercise improves behavioral, neurocognitive, and scholastic performance in children with attention-deficit/hyperactivity disorder. *The Journal of Pediatrics, 162*, 543–551. doi:10.1016/j.jpeds.2012.08.036

Prochaska, J. O., Velicer, W. F., Rossi, J. S., Goldstein, M. G., Marcus, B. H., Rakowski, W., … & Rossi, S. R. (1994). Stages of change and decisional balance for twelve problem health behaviors. *Health Psychology, 13*, 39–46. doi:10.1037/0278-6133.13.1.39

Putukian, M., Kreher, J. B., Coppel, D. B., Glazer, J. L., McKeag, D. B., & White, R. D. (2011). Attention deficit hyperactivity disorder and the athlete: An American Medical Society for Sports Medicine position statement. *Clinical Journal of Sport Medicine, 21*, 392–401. doi:10.1097/JSM.0b013e3182262eb1

Puyau, M. R., Adolph, A. L., Vohra, F. A., & Butte, N. F. (2002). Validation and calibration of physical activity monitors in children. *Obesity Research, 10*, 150–157. doi:10.1038/oby.2002.24

Rangul, V., Holmen, T. L., Kurtze, N., Cuypers, K., & Midthjell, K. (2008). Reliability and validity of two frequently used self-administered physical activity questionnaires in adolescents. *BMC Medical Research Methodology, 8*:47. doi:10.1186/1471-2288-8-47

Rapport, M. D., Kofler, M. J., Alderson, R. M., Timko, T. M., & DuPaul, G. J. (2009). Variability of attention processes in ADHD: Observations from the classroom. *Journal of Attention Disorders, 12*, 563–573. doi:10.1177/1087054708322990

Richard, L., Potvin, L., Kishchuk, N., Prlic, H., & Green, L. W. (1996). Assessment of the integration of the ecological approach in health promotion programs. *American Journal of Health Promotion, 10*, 318–328. doi:10.4278/0890-1171-10.4.318

Ridley, K., Ainsworth, B. E., & Olds, T. S. (2008). Development of a compendium of energy expenditures for youth. *International Journal of Behavioral Nutrition and Physical Activity, 5*:45. doi:10.1186/1479-5868-5-45

Roseman, I. J., Wiest, C., & Swartz, T. S. (1994). Phenomenology, behaviors, and goals differentiate discrete emotions. *Journal of Personality and Social Psychology, 67*, 206–221. doi:10.1037/0022-3514.67.2.206

Roth, D. L., & Holmes, D. S. (1987). Influence of aerobic exercise training and relaxation training on physical and psychologic health following stressful life events. *Psychosomatic Medicine, 49*, 355–365. doi:10.1097/00006842-198707000-00004

Rothney, M. P., Schaefer, E. V., Neumann, M. M., Choi, L., & Chen, K. Y. (2008). Validity of physical activity intensity predictions by ActiGraph, Actical, and RT3 accelerometers. *Obesity, 16*, 1946–1952. doi:10.1038/oby.2008.279

Rothon, C., Edwards, P., Bhui, K., Viner, R. M., Taylor, S., & Stansfeld, S. A. (2010). Physical activity and depressive symptoms in adolescents: A prospective study. *BMC Medicine, 8*:32. doi:10.1186/1741-7015-8-32

Rowlands, A. V., Thomas, P. W., Eston, R. G., & Topping, R. (2004). Validation of the RT3 triaxial accelerometer for the assessment of physical activity. *Medicine and Science in Sports and Exercise, 36*, 518–524. doi:10.1249/01.MSS.0000117158.14542.E7

Russel, J. A. (1978). Evidence of convergent validity on the dimensions of affect. *Journal of Personality and Social Psychology, 36*, 1152–1168.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psycho-logy, 39*, 1161–1178. doi:10.1037/h0077714

Russell, J. A. (1991). In defense of a prototype approach to emotion concepts. *Journal of Personality and Social Psychology, 60*, 37–47. doi:10.1037/0022-3514.60.1.37

Russell, J. A. (2005). Emotion in human consciousness is built on core affect. *Journal of Consciousness Studies, 12*, 26–42.

Russell, J. A., & Feldman Barrett, L. (1999). Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant. *Journal of Personality and Social Psychology, 76*, 805–819. doi:10.1037/0022-3514.76.5.805

Russell, J. A., & Feldman Barrett, L. (2009). Core affect. In D. Sander & K. R. Scherer (Eds.), *The Oxford companion to emotion and the affective sciences* (p. 104). New York, NY: Oxford University Press.

Russell, J. A., Weiss, A., & Mendelsohn, G. A. (1989). Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57*, 493–502. doi:10.1037/0022-3514.57.3.493

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual Review of Public Health, 27*, 297–322. doi:10.1146/annurev.publhealth.27.021405.102100

Sallis, J. F., Hovell, M. F., Hofstetter, C. R., Faucher, P., Elder, J. P., Blanchard, J., … & Christenson, G. H. (1989). A multivariate study of determinants of vigorous exercise in a community sample. *Preventive Medicine, 18*, 20–34. doi:10.1016/0091-7435(89)90051-0

Sallis, J. F., Owen, N., & Fisher, E. B. (2008). Ecological models of health behavior. In K. Glanz, B. K. Rimer, & K. Viswanath (Eds.), *Health behavior and health education: Theory, research, and practice* (pp. 465–485). San Francisco, CA: Wiley.

Sallis, J. F., Prochaska, J. J., & Taylor, W. C. (2000). A review of correlates of physical activity of children and adolescents. *Medicine and Science in Sports and Exercise, 32*, 963–975. doi:10.1097/00005768-200005000-00014

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of Science and Medicine in Sport, 14*, 411–416. doi:10.1016/ j.jsams.2011.04.003

Scherer, K. R. (1984). On the nature and function of emotion: A component process approach. In K. R. Scherer & P. E. Ekman (Eds.), *Approaches to emotion* (pp. 293–317). Hillsdale, NJ: Erlbaum.

Schmid, J. (2014). *ADHD in adolescents—symptom structure and associations with affect in daily life* (Unpublished doctoral dissertation). Goethe-Universität Frankfurt am Main, Frankfurt, Germany.

Schmid, J., Stadler, G., Dirk, J., Fiege, C., & Gawrilow, C. (accepted). ADHD symptoms in adolescents' everyday life: Fluctuations and symptom structure within and between individuals. *Journal of Attention Disorders*.

Schwarzer, R. (1992). Self-efficacy in the adoption and maintenance of health behaviors: Theoretical approaches and a new model. In R. Schwarzer (Ed.), *Self-efficacy: Thought control of action* (pp. 217–243). Washington, DC: Hemisphere.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology: An International Review, 57*, 1–29. doi:10.1111/j.1464-0597.2007.00325.x

Schwarzer, R., Lippke, S., & Luszczynska, A. (2011). Mechanisms of health behavior change in persons with chronic illness or disability: The Health Action Process Approach (HAPA). *Rehabilitation Psychology, 56*, 161–170. doi:10.1037/a0024509

Seymour, K. E., Chronis-Tuscano, A., Halldorsdottir, T., Stupica, B., Owens, K., & Sacks, T. (2012). Emotion regulation mediates the relationship between ADHD and depressive symptoms in youth. *Journal of Abnormal Child Psychology, 40*, 595–606. doi:10.1007/s10802-011-9593-4

Shacham, S. (1987). A shortened version of the Profile of Mood States. *Journal of Personality Assessment, 47*, 305–306. doi:10.1207/s15327752jpa4703_14

Sherar, L. B., Gyurcsik, N. C., Humbert, M. L., Dyk, R. F., Fowler-Kerry, S., & Baxter-Jones, A. D. (2009). Activity and barriers in girls (8–16 yr) based on grade and maturity status. *Medicine and Science in Sports and Exercise, 41*, 87–95. doi:10.1249/MSS.0b013e31818457e6

Sirard, J. R., & Pate, R. R. (2001). Physical activity assessment in children and adolescents. *Sports Medicine, 31*, 439–454. doi:10.2165/00007256-200131060-00004

Spielberger, C. D. (1972). Review of Profile of Mood States. *Professional Psychology, 3*, 387–388.

Stadler, G., & Hernandez, L. A. (in preparation). Proactive planning mediates the effect of motivation on goal achievement.

Stadler, G., Oettingen, G., & Gollwitzer, P.M. (2009). Physical activity in women: Effects of a self-regulation intervention. *American Journal of Preventive Medicine, 36*, 29–34. doi:10.1016/j.amepre.2008.09.021

Stadler, G., Wagner, S. C., Hernandez, L. A., & Gawrilow, C. (in preparation). Differential effects of proactive and reactive planning on physical activity.

Steele, R. M., van Sluijs, E. M., Cassidy, A., Griffin, S. J., & Ekelund, U. (2009). Targeting sedentary time or moderate-and vigorous-intensity activity: Independent relations with adiposity in a population-based sample of 10-y-old British children. *The American Journal of Clinical Nutrition, 90*, 1185–1192. doi:10.3945/ajcn.2009.28153

Sternfeld, B., & Goldman-Rosas, L. (2012). A systematic approach to selecting an appropriate measure of self-reported physical activity or sedentary behavior. *Journal of Physical Activity and Health, 9*(Suppl. 1), S19–28.

Strath, S. J., Kaminsky, L. A., Ainsworth, B. E., Ekelund, U., Freedson, P. S., Gary, R. A., ... & Swartz, A. M. (2013). Guide to the assessment of physical activity: Clinical and research applications A scientific statement from the American heart association. *Circulation, 128*, 2259–2279. doi:10.1161/01.cir.0000435708.67487

Stryker, L., Duncan, S., Chaumeton, N., & Toobert, D. (2007). Reliability of pedometer data in samples of youth and older women. *International Journal of Behavioral Nutrition and Physical Activity, 4*:4. doi:10.1186/1479-5868-4-4

Sund, A. M., Larsson, B., & Wichstrøm, L. (2011). Role of physical and sedentary activities in the development of depressive symptoms in early adolescence. *Social Psychiatry and Psychiatric Epidemiology, 46*, 431–441. doi:10.1007/s00127-010-0208-0

Tao, F. B., Xu, M. L., Kim, S. D., Sun, Y., Su, P. Y., & Huang, K. (2007). Physical activity might not be the protective factor for health risk behaviours and psychopathological symptoms in adolescents. *Journal of Paediatrics and Child Health, 43*, 762–767. doi:10.1111/j.1440-1754.2007.01217.x

Tellegen, A. (1985). Structures of mood and personality and their relevance to assessing anxiety, with an emphasis on self-report. In A. H. Tuma & J. D. Maser (Eds.), *Anxiety and the anxiety disorders* (pp. 681–706). Hillsdale, NJ: Erlbaum.

Tellegen, A., Watson, D., & Clark, L. A. (1999). On the dimensional and hierarchical structure of affect. *Psychological Science, 10*, 297–303. doi:10.1111/1467-9280.00157

Tergerson, J. L., & King, K. A. (2002). Do perceived cues, benefits, and barriers to physical activity differ between male and female adolescents? *Journal of School Health, 72*, 374–380. doi:10.1111/j.1746-1561.2002.tb03562.x

Thapar, A., Collishaw, S., Pine, D. S., & Thapar, A. K. (2012). Depression in adolescence. *The Lancet, 379*, 1056–1067. doi:10.1016/S0140-6736(11)60871-4

Thayer, R. E. (1967). Measurement of Activation through Self-Report. *Psychological Reports, 20*, 663–678. doi:10.2466/pr0.1967.20.2.663

Thayer, R. E. (1978). Factor analytic and reliability studies on the Activation-Deactivation Adjective Check List. *Psychological Reports, 42*, 747–756. doi:10.2466/pr0.1978.42.3.747

Thayer, R. E. (1989). *The biopsychology of mood and arousal*. New York, NY: Oxford University Press.

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*, 181–188. doi:10.l249/mss.0b013e31815a5lb3

Troiano, R. P., McClain, J. J., Brychta, R. J., & Chen, K. Y. (2014). Evolution of accelerometer methods for physical activity research. *British Journal of Sports Medicine, 48*, 1019–1023. doi:10.1136/bjsports-2014-093546

Trost, S. G. (2007). State of the art reviews: Measurement of physical activity in children and adolescents. *American Journal of Lifestyle Medicine, 1*, 299–314. doi:10.1177/1559827607301686

Tudor-Locke, C., & Bassett, D. R. (2004). How many steps/day are enough? Preliminary pedometer indices for public health. *Sports Medicine, 34*, 1–8. doi:10.2165/00007256-200434010-00001

Tudor-Locke, C., Craig, C., Beets, M., Belton, S., Cardon, G., Duncan, S., … & Blair, S. N. (2011). How many steps/day are enough? For children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity, 8*:78. doi:10.1186/1479-5868-8-78

Tudor-Locke, C., McClain, J. J., Hart, T. L., Sisson, S. B., & Washington, T. L. (2009). Pedometry methods for assessing free-living youth. *Research Quarterly for Exercise and Sport, 80*, 175–184. doi:10.1080/02701367.2009.10599551

Tudor-Locke, C., Williams, J., Reis, J., & Pluto, D. (2002). Utility of pedometers for assessing physical activity: Convergent validity. *Sports Medicine, 32*, 795–808. doi:10.2165/ 00007256-200434050-00001

U.S. Department of Health and Human Services; Physical Activity Guidelines Advisory Committee (2008). *Physical activity guidelines for Americans.* Retrieved from http://www.health.gov/paguidelines/pdf/paguide.pdf

Van Cauwenberghe, E., Gubbels, J., De Bourdeaudhuij, I., & Cardon, G. (2011). Feasibility and validity of accelerometer measurements to assess physical activity in toddlers. *International Journal of Behavioral Nutrition and Physical Activity, 8*:67. doi:10.1186/1479-5868-8-67

Van der Horst, K., Paw, M. J., Twisk, J. W., & van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine and Science in Sports and Exercise, 39*, 1241–1250. doi:10.1249/mss.0b013e318059bf35

Van Poppel, M. N., Chinapaw, M. J., Mokkink, L. B., van Mechelen, W., & Terwee, C. B. (2010). Physical activity questionnaires for adults. *Sports Medicine, 40*, 565–600. doi:10.2165/11531930-000000000-00000

Verboom, C. E., Sijtsema, J. J., Verhulst, F. C., Penninx, B. W., & Ormel, J. (2014). Longitudinal associations between depressive problems, academic performance, and social functioning in adolescent boys and girls. *Developmental Psychology, 50*, 247–257. doi:10.1037/ a0032547

Verret, C., Guay, M.-C., Berthiaume, C., Gardiner, P., & Béliveau, L. (2010). A physical activity program improves behavior and cognitive functions in children with ADHD: An exploratory study. *Journal of Attention Disorders, 16*, 71–80. doi:0.1177/ 1087054710379735

Warren, J. M., Ekelund, U., Besson, H., Mezzani, A., Geladas, N., & Vanhees, L. (2010). Assessment of physical activity—a review of methodologies with reference to epidemiological research: A report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. *European Journal of Cardiovascular Prevention & Rehabilitation, 17*, 127–139. doi:10.1097/HJR. 0b013e32832ed875

Watson, D. (2000). *Mood and temperament*. New York, NY: Guilford.

Watson, D., & Clark, L. A. (1999). The PANAS-X: *Manual for the Positive and Negative Affect Schedule (Expanded Form)*. Unpublished manuscript, University of Iowa, Iowa City.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070. doi:10.1037/0022-3514.54.6.1063

Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin, 98*, 219–235. doi:10.1037/0033-2909.98.2.219

Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology, 76*, 820–838. doi:10.1037/ 0022-3514.76.5.820

Welk, G. J. (2002). Use of accelerometry-based activity monitors to assess physical activity. In G. J. Welk (Ed.), *Physical activity assessments for health-related research* (pp. 125–142). Champaign, IL: Human Kinetics.

Weyerer, S. (1992). Physical inactivity and depression in the community. Evidence from the Upper Bavarian Field Study. *International Journal of Sports Medicine, 13*, 492–496.

Wichers, M., Peeters, F., Rutten, B. P., Jacobs, N., Derom, C., Thiery, E., … & van Os, J. (2012). A time-lagged momentary assessment study on daily life physical activity and affect. *Health Psychology, 31*, 135–144. doi:10.1037/a0025688

World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Switzerland: WHO.

World Health Organization. (2015). *International Statistical Classification of Diseases and Related Health Problems 10th Revision: ICD-10 Version: 2015*. Geneva, Switzerland: WHO.

Wu, T. Y., Pender, N., & Noureddine, S. (2003). Gender differences in the psychosocial and cognitive correlates of physical activity among Taiwanese adolescents: A structural equation modeling approach. *International Journal of Behavioral Medicine, 10*, 93–105. doi:10.1207/S15327558IJBM1002_01

Zakarian, J. M., Hovell, M. F., Hofstetter, C. R., Sallis, J. F., & Keating, K. J. (1994). Correlates of vigorous exercise in a predominantly low SES and minority high school population. *Preventive Medicine, 23*, 314–321. doi:10.1006/pmed.1994.1044

Zuckerman, M., & Lubin, B. (1965). Normative data for the Multiple Affect Adjective Check List. *Psychological Reports, 16*, 438–438. doi:10.2466/pr0.1965.16.2.438

5. Appendices

5.1 Appendix A: Manuscript I

Barriers to Physical Activity in Adolescents: A Multi-Dimensional Approach

Nadine Langguth[1], Tanja Könen[1], Simone Matulis[2], Regina Steil[2], Caterina Gawrilow[3], and Gertraud Stadler[4]

[1]Institute for International Educational Research, Germany

[2]Goethe University Frankfurt, Germany

[3]LEAD Graduate School, Eberhard Karls Universität Tübingen, Germany

[4]Department of Psychology, Columbia University, New York, USA

Author Note

Correspondence concerning this article should be addressed to Nadine Langguth, University Medical Center Hamburg-Eppendorf, Department of Child and Adolescent Psychiatry and Psychotherapy, Martinistr. 52, 20246 Hamburg, Germany, phone: +49 (0) 40 7410-58475, fax: +49 (0) 40 7410-52409, e-mail: n.langguth@uke.de

Barriers to Physical Activity in Adolescents: A Multi-Dimensional Approach

Abstract

During adolescence, physical activity (PA) decreases with potentially serious, long-term consequences for physical and mental health. Although barriers have been identified as an important PA correlate in adults, research on adolescents' PA barriers is lacking. Thus reliable, valid scales to measure adolescents' PA barriers are needed. We present two studies describing a broad range of PA barriers relevant to adolescents with a multi-dimensional approach. In Study 1, 124 adolescents (age range: 12-24 years) reported their most important PA barriers. Two independent coders categorized those barriers. The most frequent PA barriers were incorporated in a multi-dimensional questionnaire. In Study 2, 598 adolescents (age range: 13-21 years) completed this questionnaire and reported their current PA, intention, self-efficacy, and negative outcome expectations. Seven PA barrier dimensions (leisure activities, lack of motivation, screen-based sedentary behavior, depressed mood, physical health, school workload, and preconditions) were confirmed in factor analyses. A multi-dimensional approach to measuring PA barriers in adolescents is reliable and valid. The current studies provide the basis for developing individually-tailored interventions to increase PA in adolescents.

Key words: Barriers - physical activity - adolescents - questionnaire - validation

Barrieren körperlicher Aktivität von Jugendlichen: Ein mehrdimensionaler Ansatz

Zusammenfassung

Im Jugendalter sinkt die körperliche Aktivität mit potenziell schwerwiegenden, langfristigen Konsequenzen für die körperliche und psychische Gesundheit. Obwohl Barrieren als wichtiges Korrelat körperlicher Aktivität von Erwachsenen gelten, sind sie bei Jugendlichen kaum untersucht. Eine Quantifizierung der Barrieren Jugendlicher durch reliable, valide Messinstrumente ist folglich unabdingbar. In zwei Studien wurde ein breites Spektrum von Barrieren körperlicher Aktivität von Jugendlichen anhand eines mehrdimensionalen Ansatzes untersucht. In Studie 1 berichteten 124 Jugendliche (Altersbereich: 12-24 Jahre) die für sie wichtigsten Barrieren körperlicher Aktivität. Diese wurden von zwei unabhängigen Kodierern kategorisiert. Die am häufigsten genannten Barrieren gingen in die Konstruktion des mehrdimensionalen Fragebogens ein. In Studie 2 beantworteten 598 Jugendliche (Altersbereich: 13-21 Jahre) diesen Fragebogen; zudem berichteten sie ihre aktuelle körperliche Aktivität, Intention, Selbstwirksamkeit und negativen Konsequenzerwartungen. Sieben Barrieren-Dimensionen wurden mittels Faktorenanalysen bestätigt (Freizeitaktivitäten, mangelnde Motivation, Medienkonsum, depressive Stimmung, körperliche Gesundheit, schulische Arbeitsbelastung, Voraussetzungen). Die Ergebnisse zeigen, dass im Jugendalter Barrieren körperlicher Aktivität anhand eines mehrdimensionalen Ansatzes reliabel und valide erfasst werden können. Die vorliegenden Studien bilden die Grundlage, um individuell auf die Barrieren von Jugendlichen zugeschnittene Interventionen zur Steigerung ihrer körperlichen Aktivität zu entwickeln.

<u>Schlagwörter:</u> Barrieren - körperliche Aktivität - Jugendliche - Fragebogen - Validierung

Barriers to Physical Activity in Adolescents[1]: A Multi-Dimensional Approach

Regular moderate-to-vigorous physical activity (MVPA) in adolescents is associated with better physical and mental health, including better cardiometabolic parameters (e.g., systolic blood pressure, fasting triglycerides, high-density lipoprotein cholesterol, and insulin) and lower levels of depression and anxiety (Ekelund et al., 2012; for a review see Janssen & LeBlanc, 2010). However, during adolescence, MVPA decreases continuously (Nader, Bradley, McRitchie, Houts & O'Brien, 2008) with 90% of adolescents not reaching the 60 min MVPA per day that age-specific guidelines recommend (Jekauc, Reimers, Wagner & Woll, 2012; Troiano, Berrigan, Mâsse, Tilert & McDowell, 2008).

What Keeps Adolescents from Being Physically Active?

What barriers do adolescents encounter in everyday life? The importance of barriers has been explicitly or implicitly noted by most theories of health behavior change since the 1980s. However, the definitions and theoretical roles of PA barriers vary across models, as reviewed by Brawley, Martin, and Gyurcsik (1998). Barriers (i.e., constraints that might hamper or impede an individual's engagement in a health behavior; Jackson, 1988) have been studied related to self-efficacy (i.e., beliefs about one's capability to perform a health behavior even despite the presence of barriers; Bandura, 1997), negative outcome expectations (i.e., anticipated possible negative consequences of a health behavior; Bandura,

[1] Following a comprehensive review published in Lancet by Sawyers and colleagues (2012), we define the term "adolescents" as those people who are between 10 and 24 years of age.

2004; Krämer, 2014), and negative outcome experiences (i.e., actual costs of a given behavior). As Krämer and Fuchs (2010) pointed out, barriers and negative outcome expectations are distinct constructs. Negative outcome expectations, mostly conceptualized as if-then sentences (e.g., “If I am physically active, I will get laughed at”), are pre-intentional, motivational processes that emerge before an intention is formed, whereas barriers are post-intentional, volitional processes that occur before or while an intention is translated into a health behavior (Krämer, 2014; Krämer & Fuchs, 2010). Moreover, negative outcome expectations are distinct from negative outcome experiences. Expectations are solely anticipated, whereas experiences actually occur. In addition, negative outcome experiences can only be reported after a health behavior has been performed; barriers, however, are perceived before or while a health behavior is carried out.

In the health belief model (Janz & Becker, 1984) barriers were conceptualized as negative outcome expectations. Within the social cognitive theory (SCT), Bandura (2004) distinguished various categories of barriers (e.g., personal, social, environmental, or structural) and emphasized that self-efficacy influences a health behavior through its impact on barriers. In addition, Bandura (2006) stated that self-efficacy requires the presence of barriers because without barriers a target behavior could be performed easily and all individuals would be self-efficacious. The theory of planned behavior (TPB; Ajzen, 1985) regarded barriers as part of perceived behavioral control that is determined by an individual’s control beliefs (i.e., beliefs about the presence of factors that could facilitate or impede a health behavior). Within the first published version of the health action process approach (HAPA; Schwarzer, 1992), barriers were located in the perceived and actual environment (e.g., lack of social support) and were conceptualized as post-intentional, volitional constructs. Since then, barriers have always played an important part in the HAPA. However, the most current version of the HAPA (Schwarzer, 2008; Schwarzer, Lippke &

Luszczynska, 2011) integrates barriers predominantly with (action, coping, and barrier) self-efficacy with the result that barriers are measured exclusively within the framework of self-efficacy and not as a distinct construct. Following the HAPA (Schwarzer, 1992, 2008; Schwarzer et al. 2011), in Study 1 and 2 we locate adolescent-generated PA barriers within the post-intentional, volitional phase of the HAPA and studied mainly those PA barriers closely linked to barrier self-efficacy. Although barriers have been identified as important PA correlates in adults (Bauman et al., 2012), the findings in adolescents for the link between PA barriers and behavior are mixed (e.g., Biddle, Atkin, Cavill & Foster, 2011; Sallis, Prochaska & Taylor, 2000; Uijtdewilligen et al. 2011; Van der Horst, Paw, Twisk & van Mechelen, 2007).

How to Assess Barriers to Physical Activity in Adolescents?

Two limitations of the research on the PA barrier-behavior link in adolescents could contribute to these mixed findings: the use of varying assessment approaches and varying theoretical models. First, studies of PA barriers in adolescents have mainly relied on researcher-generated scales originally developed for adults (e.g., De Bourdeaudhuij & Sallis, 2002). Among the most commonly studied PA barriers in adults are lack of time due to work and family obligations, lack of motivation, health problems, access (lack of money and equipment, distance to facilities), and lack of skills (Gyurcsik, Spink, Bray, Chad & Kwan, 2006; Withall, Jago & Fox, 2011). There are several questionnaires addressing PA barriers in adults (e.g., Brown, 2005; Heesch, Mâsse & Dunn, 2006; for a German questionnaire, see Krämer & Fuchs, 2010). However, adolescence is a developmental period with specific challenges. Developing close peer relationships, renegotiating relationships with parents, establishing a unique sense of identity, expressing more complex and intensive emotions, managing multiple demands, and taking over responsibility are among the most important developmental tasks throughout adolescence (Dreher & Dreher, 1985; Havighurst, 1948). It is plausible that adults and adolescents show some overlap in PA barriers (e.g., lack of motivation or lack of skills), merely adapting adult-reported PA barriers to adolescents, however, does not do justice to this particular developmental period and appears to be inappropriate.

Qualitative research highlighted additional PA barriers in adolescents: meeting up with peers, competing interests, involvement in technology-related activities, and school workload (e.g., Dwyer, Allison, Goldenberg, Fein, Yoshida & Boutilier, 2006; for an overview see Pate, Saunders, O'Neill & Dowda, 2011). But reliable and valid scales for assessing PA barriers relevant to adolescents' everyday life are missing. If researchers succeed in assessing adolescents' PA barriers in a reliable and valid way, targeted interventions implementing specific barrier management strategies could be developed. Depending on the PA barriers that an adolescent perceives, personally tailored barrier management strategies and coping plans could be provided to improve PA in this age group being at risk for developing an inactive lifestyle.

Theoretical Models of Barriers to Physical Activity

Second, the theoretical models used so far ranged from assuming single, dual, to multiple barrier dimensions and this could also contribute to the mixed findings for the link between PA barriers and behavior in adolescents. Unidimensional (i.e., general barrier) models treat all barriers as equal resulting in a mean barrier score. However, the assumption that each PA barrier will contribute equally to the prediction of behavior seems to be unlikely (De Bourdeaudhuij, Sallis & Vandelanotte, 2002). Two-dimensional (i.e., internal and external barriers) models have challenged the assumptions of unidimensional models. One qualitative study in a sample of high-school students differentiated internal (i.e., personal) PA barriers such as lack of motivation from external (i.e., environmental) PA barriers such as having a heavy workload (Allison, Dwyer & Makin, 1999). Although this study provided a more detailed view of PA barriers than studies using a unidimensional model, both uni- and two-dimensional barrier models appear to be too unspecific for developing targeted PA interventions by reducing PA barriers in adolescents (Gyurcsik et al., 2006).

Consequently, investigating more and varying PA barriers by applying a multi-dimensional approach is particularly needed. In recent years, models of PA promotion with multiple interacting levels (personal, social, environmental, organizational, and policy-related) have received increasing attention (Sallis, Owen & Fisher, 2008; Sherar et al., 2009). In their qualitative examination of adolescents' PA barriers, Gyurcsik and colleagues (2006) assigned adolescents' answers to open-ended questions to either intrapersonal (e.g., lack of motivation), interpersonal (e.g., inactive friends), institutional (e.g., school workload), community-based (e.g., lack of transportation), environmental (e.g., lack of safety), or public policy-related PA barrier categories (e.g., laws that prohibit playing soccer in parks). Adolescents mainly reported intrapersonal, interpersonal, and institutional PA barriers. They rarely mentioned community-based and environmental PA barriers, and public policy-related PA barriers not at all (Gyurcsik et al., 2006). Interestingly, adolescents considered only three PA barrier categories as relevant to their everyday life. Considering that particularly the intrapersonal barrier category includes everything from lack of motivation and lack of skills to lack of money to health problems, a more fine-grained assessment would be more suitable to develop targeted PA barrier management strategies.

Research Aims and Hypotheses of the Current Studies

To address the shortcomings of previous studies, we conducted two studies. In Study 1 (item generation and questionnaire development), adolescents generated their most important PA barriers. Two independent coders categorized the content of all adolescent-generated PA barriers. Based on the most frequently mentioned PA barriers in Study 1, Study 2 (questionnaire validation) examined the dimensional structure of these PA barriers by conducting factor analyses as well as their relationship with PA and established PA correlates. To establish criterion validity, we studied the link between the derived PA barrier dimensions and PA and intention, respectively. To determine discriminant validity, we investigated the association between PA barrier dimensions and self-efficacy and negative outcome expectations, respectively. Besides PA barriers, intention, self-efficacy, and negative outcome expectations are among the most commonly studied PA correlates (Bauman et al., 2012). Barriers are known to have a negative impact on intention (Ajzen, 1985) and self-efficacy (Schwarzer, 2008). Moreover, there is evidence that particularly vigorous PA is inversely related to adolescents' PA barriers (Allison et al., 1999; Biddle et al., 2011; Gyurcsik, Bray & Brittain, 2004). Study 2 tested the following hypotheses: We expected that a model with several discrete PA barrier dimensions would show better fit to the data than uni- and two-dimensional models (Hypothesis 1). Moreover, we expected that the derived PA barrier dimensions would correlate negatively with moderate, moderate-to-vigorous, and vigorous PA, in particular, as well as with intention to PA (criterion validity; Hypothesis 2). In addition, we expected that the derived PA barrier dimensions would correlate negatively with PA self-efficacy and negative outcome expectations of PA (discriminant validity; Hypothesis 3).

Study 1: Item Generation and Questionnaire Development

Methods

Participants

In Study 1, which was part of a daily diary study on the link between accelerometer-based PA and affect, 124 adolescents participated; 118 participants reported at least one PA barrier (age: M = 18.17±3.08 years, range: 12-24 years; 68% males). All participants attended public secondary schools (grades 7-12) in a large urban area in Germany, with 89% aiming at a higher education entrance qualification. Most participants (85%) were born in Germany;

56% had at least one parent born in another country; 50% had at least one parent with a college education or higher, of whom 33% had a university degree. Based on accelerometry, participants (n = 84) spent on average 78.23± 37.01 min per day with MVPA; 64% of participants reached the MVPA guidelines for this age group (World Health Organization, WHO, 2010).

Procedure

Participants were assured that their participation would be voluntary and their answers would remain confidential. The research protocol was approved by the local Institutional Review Board. Data were collected between September and December 2011. All participants provided written informed consent.

Measures

Participants were asked to generate PA barriers with an open-ended format. Participants were instructed to write down up to six situations, events, people, thoughts, or feelings that kept them from being physically active in the past week.

Analyses

Following the approach by Gyurcsik and colleagues (2006), similar PA barriers were grouped together and labeled (preliminary categories: cognitive, emotional, motivational, physical, social, environmental, institutional PA barriers as well as lack of equipment and money, other leisure activities, and sedentary activities). Preliminary categories were based on the current literature on PA barriers in adolescents (e.g., Goh et al., 2009; Gyurcsik et al., 2006; Pate et al., 2011). Two coders categorized 10% of all open-ended answers and resolved disagreements by discussion. Then, both coders categorized the remaining 90% independently (Cohen's Kappa κ = .96).

Results

In Study 1, participants generated a total of 602 actually perceived PA barriers with a great overlap of responses (on average 5.02 PA barriers per participant). The selection process was guided by two criteria: adolescent-generated PA barriers should cover a broad range and should be salient to most adolescents of Study 1. We excluded very unusual PA barriers (e.g., “Smoking a joint”, “Driving test”), non-specific PA barriers (e.g., “Me”, “Lack of time”), or ambiguous PA barriers (e.g., “Prioritization”, “Other things”). Thus, we selected the 46 *most frequently* reported, actually perceived PA barriers for Study 2.

Study 2: Questionnaire Validation

Methods

Participants

In Study 2, 598 adolescents participated (age: M = 17.44±1.98 years, range: 13-21 years; 68% males). All participants attended public secondary schools (grades 8-13) in a large urban area in Germany, with 81% aiming at a higher education entrance qualification. Most participants (90%) were born in Germany; 43% had at least one foreign-born parent; 47% had at least one parent with a college education or higher, of whom 28% had a university degree. Based on the International Physical Activity Questionnaire – Short Form (IPAQ-SF, Craig et al., 2003), participants spent on average 91.35± 82.56 min per day with MVPA; 56% of participants accomplished the MVPA guidelines for this age group (WHO, 2010).

Procedure

In Study 2, data were collected between March and May 2012. Trained research assistants informed adolescents about the study in class, handed out a written study description, and encouraged them to ask questions. Adolescents were assured that their participation would be voluntary and their answers would remain anonymous. Participating adolescents provided verbal informed consent. They were taken to the school hall where each participant completed a package of measures at a single desk. The research protocol was approved by the local Institutional Review Board.

Measures

Barriers to physical activity. Participants rated 46 PA barriers (e.g., "I rather watched TV") which they might have actually experienced using a 4-point scale ranging from 1 (*not at all*) to 4 (*very much*) with the following instruction: "Several situations are listed below that may keep adolescents from being physically active. Please indicate how strongly each barrier kept you from being physically active *during the last week*".

Physical activity. We assessed PA through the 7-items version of the IPAQ, the IPAQ-SF—a frequently used, self-administered PA questionnaire, suitable for the assessment of PA in adolescents (Lopes, Gabbard & Rodrigues, 2013). Participants were asked to indicate the frequency (days per week) and duration (min per day) of moderate and vigorous PA as well as walking with reference to the past seven days. In addition, participants reported the duration of sitting for that particular time frame. We computed min per week of moderate and vigorous PA, as well as MVPA and walking. Validation studies have shown correlations between IPAQ walking and step counts as well IPAQ vigorous PA and maximal oxygen consumption, an indicator of an individual's cardiorespiratory fitness (for a review, see Lee, Macfarlane, Lam & Stuart, 2011). With regard to adolescents, the IPAQ-SF shows an acceptable correlation between light-to-vigorous PA as well as vigorous PA and maximal oxygen consumption (Rangul, Holmen, Kurtze, Cuypers & Midthjell, 2008).

Intention, self-efficacy, and negative outcome expectations. Following Krämer and Fuchs (2010), we measured PA intention with a single item ("Regarding last week, how strong was your intention to be physically active?") using a 4-point scale ranging from 1 (*not at all strong*) to 4 (*very strong*) and PA self-efficacy with three items ("I think I will be able to start being physically active," "to maintain PA for several months," and "to start being physically active again after a long pause") using a 6-point scale ranging from 1 (*not at all true*) to 6 (*exactly true*). For PA self-efficacy, Cronbach's alpha was $\alpha = .79$. Following Fuchs (1994), we assessed negative outcome expectations of PA with 13 items (e.g., "If I am physically active, I will get laughed at") on a 4-point scale ranging from 1 (*not at all true*) to 4 (*completely true*). For negative outcome expectations of PA, Cronbach's alpha was $\alpha = .76$.

Analyses

In Study 2, we divided the sample ($N = 598$) into two random subsamples (Subsample A: $n = 400$; Subsample B: $n = 198$) and conducted the main analyses with Mplus 7.0 in three basic steps. First, we performed an exploratory factor analysis (EFA) with maximum likelihood (ML) estimation and oblimin rotation in Subsample A. An advantage of using Mplus is that results of EFA can be interpreted by means of established continuous fit indices enabling researchers to make an informed choice about the number of factors to extract (for a review see Fabrigar, Wegener, MacCallum & Strahan, 1999). Model fit was evaluated with the χ^2-test, the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). We chose the first solution with a good model fit resulting in a minimum number of factors. Item selection was based on EFA results. Only items showing their highest and significant EFA loading on a barrier factor were selected to represent that factor.

Second, we tested the resulting model with a confirmatory factor analysis (CFA) in Subsample B by using MLR estimation (ML with robust standard errors). We evaluated the model fit by using χ^2-test, CFI, RMSEA, and SRMR (Beauducel & Wittmann, 2005). For model identification, we fixed the first loading of each factor to one. We allowed all factors to correlate. To underline the strength of our CFA results, we also provided a bootstrapped version of the CFA. We decided to use a subsample of two-third of all participants for the

EFA and one-third for the CFA, as the exploratory part includes all items and is the basis for item selection. Both subsamples fulfill common sample size suggestions for EFA and CFA, respectively (e.g., Bühner, 2011).

Third, we correlated all barrier factors with validity criteria (PA and PA intention to establish criterion validity, PA self-efficacy and negative outcome expectations of PA to examine discriminant validity) by means of MLR estimation (Subsample B). To examine the quality of each barrier item, we performed an item analysis by using SPSS 21.0. Internal consistencies (Cronbach’s alpha) were computed.

Results

In Study 2, in a first step, we conducted an EFA with ML estimation and oblimin rotation with all 46 barrier items in Subsample A (n = 400). Fit indices for one- to eight-factor models are shown in Table 1. The fit of a one-factor solution up to a five-factor solution was unacceptable. Naturally the fit becomes better with more factors being extracted. We aimed at identifying the first model with an acceptable fit but the most parsimonious model according to the number of factors. The six-factor model tended towards a satisfactory fit, but the CFI was still under .90. The seven-factor model was the first with an acceptable fit in all indices. To prevent over-factoring, we specified that (a) all factors had to be represented by at least three significant items showing their highest loading on that factor and (b) all items of a factor should theoretically integrate to a plausible dimension. As the seven-factor solution did fully meet these criteria, we extracted seven factors (leisure activities, lack of motivation, screen-based sedentary behavior, depressed mood, physical health, school workload, and preconditions). All eigenvalues were above one, with the smallest eigenvalue 1.49 for physical health. Only items showing their highest significant loading on a factor were selected to represent that factor resulting in 25 out of 46 items with factor loadings between .35 and .86.

[TABLE 1 INSERT HERE]

In a second step, we conducted a CFA with MLR estimation in Subsample B (n = 198). We used the seven-factor solution of the EFA resulting in 25 items. The model showed a descriptively acceptable fit, χ^2(df = 254) = 391.90, p < .01, CFI = .90, RMSEA = .05 (90% CI = .04-.06), and SRMR = .06. All factors had meaningful variances and all standardized factor loadings were significant and over .48. Significant factor intercorrelations ranged between .24 (screen-based sedentary behavior and physical health) and .79 (leisure activities and lack of motivation), implying discrete but dependent dimensions (Figure 1). The factor correlation of .79 was the only one high enough to question the uniqueness and necessity of both factors. However, fixing the factor correlation to 1 resulted in a significantly worse model fit ($\Delta\ \chi^2$ (df =1) = 22.74, p < .01; Satorra-Bentler scaled χ^2-difference test; Satorra & Bentler, 2001), implying that both factors cannot be subsumed to one.

For the presentation of results, we bootstrapped the CFA three times with a Bollen-Stine bootstrap. We extracted 200, 250, and 300 draws from Subsample B. All requested draws were completed in all three sequences. The new model fit was χ^2(df = 254) = 464.39, p = .06, CFI = .89, RMSEA = .07 (90% CI = .06-.07), and SRMR = .06 for the three draws. The bootstrap p-value was insignificant three times, indicating an acceptance of our CFA model. All factor loadings were significant (p < .01) in all three draws. Therefore, the bootstrapped CFA was in line with the MLR estimation.

[FIGURE 1 INSERT HERE]

We also investigated the fit of a uni- (i.e., general barriers) and a two-dimensional model (i.e., internal and external barriers) to the selected 25 items and tested both against our seven-factor model (Subsample B, MLR estimation). A one-factor model revealed an unacceptable fit, χ^2(df = 275) = 985.85, p < .01, CFI = .50, RMSEA = .11 (90% CI = .11-.12), and SRMR = .12, as did a two-factor model with internal and external barriers, χ^2(df =

274) = 781.97, $p < .01$, CFI = .64, RMSEA = .10 (90% CI = .09-.11), and SRMR = .12. Both, the uni- and the two-factor model, were significantly worse than the seven-factor comparison model, $\Delta\ \chi^2$ ($df = 21$) = 394.59, $p < .01$ (for the one-factor model) and $\Delta\ \chi^2$ ($df = 20$) = 267.63, $p < .01$ (for the two-factor model; Satorra-Bentler scaled χ^2-difference test).

We then correlated the seven barrier factors with three validity criteria (Subsample B, MLR estimation). Vigorous PA correlated negatively with all barrier factors, except preconditions and physical health. PA intention and self-efficacy were negatively associated with the barrier dimensions leisure activities, lack of motivation, screen-based sedentary behavior, and depressed mood. PA self-efficacy was also inversely related to the barrier dimension of preconditions. There was no significant association between PA intention and self-efficacy to the barrier dimensions of school workload and physical health. Negative outcome expectations of PA correlated positively with all barrier dimensions. Correlations between PA barriers and PA, PA intention, PA self-efficacy, and negative outcome expectations are described in Table 2. Results of the item analysis can be found in Table 3.

[TABLE 2 INSERT HERE]

[TABLE 3 INSERT HERE]

General Discussion

Study 1 and Study 2 aimed to gain a better insight into PA barriers relevant to adolescents. We developed (Study 1) and validated (Study 2) a multi-dimensional PA barrier questionnaire, particularly adapted for this age group. In Study 1, adolescents generated PA barriers. After two independent coders categorized all adolescent-generated PA barriers based on the current literature, 46 common PA barriers covering a broad range were selected for Study 2. In Study 2, we found a multi-dimensional structure of PA barriers indicating that adolescents perceive a wide range of barriers. In line with Hypothesis 1, a multi-dimensional PA barrier model outperformed a uni- and a two-dimensional model suggesting that both approaches (i.e., treating all PA barriers as equal, unidimensional model; dividing PA barriers into internal and external categories, two-dimensional model) are suboptimal ways to measure PA barriers in adolescents. We confirmed seven discrete but related barrier dimensions comprising 25 PA barriers: leisure activities, lack of motivation, screen-based sedentary behavior, depressed mood, physical health, school workload, and preconditions.

Barrier Dimension 1, leisure activities, included meeting with peers, other favored weekend activities, and other favored hobbies. During adolescence, developmental tasks like developing close and stable peer relationships and establishing a unique sense of identity (like exploring varying leisure activities within a peer social network) become increasingly important. As leisure time priorities are known to change during adolescence (Slater & Tiggemann, 2010; Whitehead & Biddle, 2008), a discrete barrier dimension capturing leisure activities appears to be particularly needed for this age group. In line with De la Haye, Robins, Mohr and Wilson (2011), there is also evidence that adolescents tend to adopt their friends' PA behavior. Thus, meeting with less active peers presents a central PA barrier on its own for adolescents. Barrier Dimension 2, lack of motivation, corresponded to adolescents' feelings of fatigue and laziness (not feeling like it, being too tired, and being too lazy), a common PA barrier in adolescents (Saxena, Borzekowski & Rickert, 2002). Screen-based sedentary activities (surfing the internet, watching TV, and playing computer games), Barrier Dimension 3, are popular recreational activities of adolescents known to compete with their PA behavior (Dwyer et al., 2006; Wong et al., 2010). Barrier Dimension 4, depressed mood (feeling blue, mulling things over, and bad mood) and mood swings are associated with the developmental task of expressing more complex and intense emotions, making it harder for adolescents to engage in PA, consistent with previous research (Birkeland, Torsheim & Wold, 2009; Sabiston et al., 2013). Barrier Dimension 5 (physical health) contained illness and injuries. Health problems like asthma are known to be an important barrier to PA (Glazebrook et al., 2006), despite being less commonly reported by our sample. Barrier Dimension 6, school workload, encompassed large amounts of homework, long schooldays, and exam preparation. Managing school obligations is associated with graduating and preparing for the labor market. This central developmental task in adolescence is among the most important PA barriers in this age group (e.g., Allison et al., 1999). Barrier Dimension 7, preconditions, also less frequently reported by our sample, comprised high costs, long distance to recreational facilities, and low perceived control over being physically active. These barriers are known to keep adolescents from PA, particularly those of low socioeconomic status (Withall et al., 2011).

As expected in Hypothesis 2, most PA barriers correlated negatively with vigorous PA, in line with previous research (Allison et al., 1999; Gyurcsik et al., 2004). Preconditions and physical health were not related to PA indicating that our participants may have had favorable conditions to PA and were in good health. Walking and moderate PA were less strongly associated with barriers suggesting that adolescents perceived vigorous PA as more demanding or as the prototype of PA when reporting PA barriers. Moreover, vigorous PA is perhaps more salient to adolescents since it is commonly pre-planned (e.g., playing basketball in a sports club at a definite time). PA intention was only negatively associated with leisure activities, lack of motivation, screen-based sedentary behavior, and depressed mood. PA self-efficacy was inversely related to all PA barrier dimensions except school workload and physical health. Interestingly, these PA barriers are predominantly open to adolescents' influence (as opposed to physical health and school workload being outside of adolescents' control) and, therefore, can be considered as intrapersonal in the broadest sense. As PA intention and PA self-efficacy are cognitive PA correlates, they can be referred to as intrapersonal as well. Hence, it may be not surprising that PA correlates that are considered intrapersonal and can basically be changed by adolescents themselves are interrelated. As expected, negative outcome expectations of PA were positively associated with all PA barrier dimensions. The low correlations we found between both variables correspond to previous research (Krämer & Fuchs, 2010) and support our assumption that PA barriers are actually distinct from negative outcome expectations of PA. Hence, both criterion validity (negative correlations between PA barriers and PA as well as between PA barriers and intention; Hypothesis 2) and discriminant validity (negative correlations between PA barriers and self-efficacy as well as positive correlations between PA barriers and negative outcome expectations; Hypothesis 3) of our multi-dimensional PA barrier questionnaire were largely supported.

Our two studies make a number of contributions. First, we focused on PA barriers that adolescents self-generated spontaneously. Participants of both studies lived in a large urban area in Germany with walkable, safe neighborhoods, and good opportunities for PA (Buehler, Pucher, Merom & Bauman, 2011). As such, these studies address PA barriers when the environment is favorable. These results are a good starting point for developing, improving, and testing psychosocial interventions (i.e., coping planning) to tackle the adolescent-perceived PA barriers we found. Adolescents living in environments with less favorable conditions to PA will likely benefit from these psychosocial interventions, too, but will need complementary environmental interventions to encourage PA (De Meester, Van Dyck, De Bourdeaudhuij, Deforche & Cardon, 2013). Second, as Study 1 followed a qualitative research approach, only PA barriers particularly relevant to adolescents were investigated in Study 2. This means that in addition to numerous well-studied PA barriers (Pate et al., 2011) PA barriers like screen-based sedentary activities—central to adolescents' everyday life—were studied as well. Third, in Study 2, the validation of a multi-dimensional PA barrier questionnaire was based on a large sample of adolescents, comparable to those who participated in Study 1, with diverse social and ethnic backgrounds, allowing for increased generalizability. Fourth, as opposed to many other researchers, using predominantly principal component analysis (PCA), we conducted CFA to evaluate the multi-dimensional nature of adolescents' PA barriers. As opposed to PCA, CFA is the only suitable method for explaining item interrelations and testing, whether complex data fit a hypothesized model.

Despite its contributions, Study 2 has some limitations. First, adolescents retrospectively reported their PA barriers with reference to the last week. Self-report instruments can be biased. However, the short recall period should facilitate recall from memory and alleviate bias and heuristics use, leading to more valid results than longer or nonspecific reference periods in similar studies (e.g., "generally", Allison et al., 1999; De Bourdeaudhuij & Sallis, 2002; Krämer & Fuchs, 2010; "barriers within the last six months", Gyurcsik et al., 2006). Second, we did not assess adolescents' environmental conditions to PA such as neighborhood walkability, because the environment was universally walkable and safe (Buehler et al., 2011) and was very rarely reported as a PA barrier in Study 1. Environmental PA barriers may be more important for adolescents in neighborhoods less conducive to PA. However, our study shows that even in environments that are walkable and safe adolescents still encounter psychosocial barriers that keep them from being active and thus deserve research attention. Third, as most other PA self-report questionnaires (Adamo, Prince, Tricco, Connor-Gorber & Tremblay, 2009; Prince et al., 2008), the IPAQ-SF (Craig et al., 2003) tends to overestimate the actual amount of PA. Probably due to the reference period (i.e., the last seven days), the IPAQ-SF shows a low test-retest reliability. It can be assumed that PA may vary considerably from week to week, especially among younger adolescents (Rangul et al., 2008). However, light-to-vigorous PA as well as vigorous PA as measured by the IPAQ-SF show an acceptable correlation with cardiorespiratory fitness in adolescents (Rangul et al., 2008). A next step of this research program will be the assessment of PA with accelerometers in addition to self-report. In both studies participants tended to be rather physically active. In future studies, more physically inactive participants should be included to test whether physically inactive participants report qualitatively other PA barriers compared to physically active participants. Fourth, when studying a broad age range as was the case in the current studies, it would be desirable to examine larger and equally sized age groups. Fifth, when studying PA barriers and their association with other social-cognitive variables in future studies, three further aspects should be considered. Recent models of health behavior change such as the HAPA (Schwarzer, 2008; Schwarzer et al., 2011) differentiate social-cognitive processes that lead to forming a goal (motivational processes) from processes after a goal has been set (volitional processes). Thus, the phase-specificity of social-cognitive variables including PA barriers should be examined more carefully in future research. Future studies should investigate action, coping, and barrier self-efficacy together to distinguish their specific relationships with various PA barriers. However, in Study 1, adolescents self-generated solely those PA barriers closely linked to the concept of barrier self-efficacy (e.g., “I am confident that I will engage in regular PA, even if I feel depressed”; Renner et al., 2012). Barriers that are addressed by action self-efficacy (i.e., lack of goal setting and planning ability; e.g., “I am confident that I will engage in regular PA, even if I have to make a detailed plan”; Renner et al., 2012) and coping self-efficacy (i.e., lack of perseverance and social support; e.g., “I am confident that I will engage in regular PA, even if I have to try several times until it works”; Renner et al., 2012) did not cross adolescents' minds when being asked to report their most important PA barriers. Nevertheless, examining PA barriers that are related to action and coping self-efficacy seems promising and it would be very interesting to study whether adolescents can become more aware of these types of barriers. Moreover, measuring self-efficacy more comprehensively with multiple items and differentiating action, coping, and barrier self-efficacy (Renner et al., 2012; Scholz et al., 2005; Schwarzer & Renner, 2000) could lead to even higher correlations between barriers and self-efficacy than those found in Study 2. Moreover, besides negative outcome expectations (in the motivational phase), negative outcome experiences (i.e., actual costs) of being physically active (in the volitional phase) should also be measured to differentiate negative outcome experiences from barriers of PA. Finally, further health-related cognitions that emerge in the volitional phase such as action planning (i.e., a person specifies where, when, and how he or she will be physically active) and coping planning (i.e., a person anticipates possible PA barriers and considers an alternative behavior to overcome these PA barriers) should be assessed as additional validity criteria in future research (Renner et al., 2012).

Study 1 and Study 2 have important implications for the development of targeted PA interventions. Given the need for intervention programs and their limited success (Bauman et al., 2012; Metcalf, Henley & Wilkin, 2012) the development of PA barrier management strategies that are tailored to discrete PA barrier dimensions could be promising. Using a comprehensive barrier questionnaire as a step within PA interventions may help participants to become aware of a range of PA barriers—not only the most salient ones. Adolescents could then also generate additional barriers that are too infrequent to include in a questionnaire. Coping planning as well as using facilitators such as social support could be intervention strategies to address these barriers. Using planning not only to react to barriers once they occur but rather to preventively circumvent potential PA barriers could improve intervention effects further (Stadler, Oettingen & Gollwitzer, 2009). Study 2 has additional theoretical implications. Barrier self-efficacy emerges primarily in the volitional phase of the HAPA, that is, during the period of adaption and maintenance of a target health behavior (Renner et al., 2012). But some barriers could also impede the formation of intentions. Future studies should examine if some barriers emerge predominantly in the motivational phase (e.g., lack of planning ability, lack of motivation, chronic illness) and impact most likely the formation of an intention, while others rather impact volitional processes (e.g., lack of social support or perseverance, heavy school workload, acute illness), i.e., the adaptation and maintenance of a health behavior.

To conclude, both studies revealed that a multi-dimensional approach to measuring PA barriers in adolescents is reliable and valid. Hence, the current studies will contribute to a better understanding of how to address a broad range of adolescents' PA barriers in health research and practice.

References

Adamo K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S. & Tremblay, M. (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: A systematic review. *International Journal of Pediatric Obesity, 4*, 2–27.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckmann (Eds.), *Action control: From cognition to behavior* (pp. 11-40). Berlin: Springer.

Allison, K. R., Dwyer, J. J. M. & Makin, S. (1999). Perceived barriers to physical activity among high school students. *Preventive Medicine, 28*, 608–615.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education and Behavior, 31*, 143–164.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. C. Urdan (Eds.), *Self-efficacy beliefs of adolescents* (pp. 307–337). Greenwich, CT: IAP.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F. & Martin, B. W. (2012). Correlates of physical activity: why are some people physically active and others not? *Lancet, 380*, 258–271.

Beauducel, A. & Wittmann, W. W. (2005). Simulation study on fit indices in confirmatory factor analysis based on data with slightly distorted simple structure. *Structural Equation Modeling, 12*, 41–75.

Biddle, S. J. H., Atkin, A. J., Cavill, N. & Foster, C. (2011). Correlates of physical activity in youth: a review of quantitative systematic reviews. *International Review of Sport and Exercise Psychology, 4*, 25–49.

Biddle, S. J. H. & Mutrie, N. (Eds.). (2008). *Psychology of physical activity: Determinants, well-being, and interventions*. New York, NY: Routledge.

Birkeland, M. S., Torsheim, T. & Wold, B. (2009). A longitudinal study of the relationship between leisure time physical activity and depressed mood among adolescents. *Psychology of Sport and Exercise, 10*, 25–34.

Brawley, L. R., Martin, K. A. & Gyurcsik, N. C. (1998). Problems in assessing perceived barriers to exercise: Confusing obstacles with attributions and excuses. In J. L. Duda (Ed.), *Advances in measurement in sport and exercise psychology* (pp. 337-350). Morgantown, WV: Fitness Information Technology.

Brown, S. (2005). Measuring perceived benefits and perceived barriers for physical activity. *American Journal of Health Behavior, 29*, 107–116.

Buehler, R., Pucher, J., Merom, D. & Bauman, A. (2011). Active travel in Germany and the U.S. Contributions of daily walking and cycling to physical activity. *American Journal of Preventive Medicine, 41*, 241–250.

Bühner, M. (Ed.). (2011). *Einführung in die Test- und Fragebogenkonstruktion* [Introduction to test construction and questionnaire development]. München: Pearson Studium.

Craig, C. L., Marshall, A. L., Sjostrom, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E. et al. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise, 35*, 1381–1395.

De Bourdeaudhuij, I. & Sallis, J. F. (2002). Relative contribution of psychosocial variables to the explanation of physical activity in three population-based adult samples. *Preventive Medicine, 34*, 279–288.

De Bourdeaudhuij, I., Sallis, J. F. & Vandelanotte, C. (2002). Tracking and explanation of physical activity in young adults over a 7-year period. *Research Quarterly for Exercise and Sport, 73*, 376–385.

De la Haye, K., Robins, G., Mohr, P. & Wilson, C. (2011). How physical activity shapes, and is shaped by, adolescent friendships. *Social Science & Medicine, 73*, 719–728.

De Meester, F., Van Dyck, D., De Bourdeaudhuij, I., Deforche, B. & Cardon, G. (2013). Do psychosocial factors moderate the association between neighborhood walkability and adolescents' physical activity? *Social Science & Medicine, 81*, 1–9.

Dreher, E. & Dreher, M. (1985). Entwicklungsaufgaben im Jugendalter: Bedeutsamkeit und Bewältigungskonzepte [Developmental tasks in adolescence: Meaning and coping concepts]. In D. Liepmann & A. Stiksrud (Eds.), *Entwicklungsaufgaben und Bewältigungsprobleme in der Adoleszenz* (pp. 56–70). Göttingen: Hogrefe.

Dwyer, J. J., Allison, K. R., Goldenberg, E. R., Fein, A. J., Yoshida, K. K. & Boutilier, M. A., (2006). Adolescent girls' perceived barriers to participation in physical activity. *Adolescence, 41*, 75–89.

Ekelund, U., Luan, J., Sherar, L. B., Esliger, D. W., Griew, P. & Cooper, A. (2012). Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *Journal of the American Medical Association, 307*, 704–712.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C. & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4*, 272–299.

Fuchs, R. (1994). Konsequenzerwartungen als Determinante des Sport- und Bewegungsverhaltens. *Zeitschrift für Gesundheitspsychologie, 2*, 269–291.

Glazebrook, C., McPherson, A. C., Macdonald, I. A., Swift, J. A., Ramsay, C., Newbould, R. et al. (2006). Asthma as a barrier to children's physical activity: implications for body mass index and mental health. *Pediatrics, 118*, 2443–2449.

Goh, Y.-Y., Bogart, L. M., Sipple-Asher, B. K., Uyeda, K., Hawes-Dawson, J., Olarita-Dhungana et al. (2009). Using community-based participatory research to identify potential interventions to overcome barriers to adolescents' healthy eating and physical activity. *Journal of Behavioral Medicine, 32*, 491–502.

Gyurcsik, N. C., Bray, S. R. & Brittain, D. R. (2004). Coping with barriers to vigorous physical activity during transition to university. *Family & Community Health, 27*, 130–142.

Gyurcsik, N. C., Spink, K. S., Bray, S. R., Chad, K. & Kwan, M. (2006). An ecologically based examination of barriers to physical activity in students from grade seven through first-year university. *Journal of Adolescent Health, 38*, 704–711.

Havighurst, R. J. (1948). *Developmental task and education*. Chicago, IL: University of Chicago.

Heesch, K., Mâsse, L. & Dunn, A. (2006). Using Rasch modeling to re-evaluate three scales related to physical activity: Enjoyment, perceived benefits and perceived barriers. *Health Education Research, 21*, 58–72.

Jackson, E. L. (1988). Leisure constraints: A survey of past research. *Leisure Sciences, 10*, 203–215.

Janssen I. & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(40).

Janz, N. K. & Becker, M. H. (1984). The health belief model: A decade later. *Health Education Quarterly, 11*, 1–47.

Jekauc, D., Reimers, A. K., Wagner, M. O. & Woll, A. (2012). Prevalence and socio-demographic correlates of the compliance with the physical activity guidelines in children and adolescents in Germany. *BMC Public Health, 12*(714).

Krämer, L. (2014). Barrieren, gesundheitsbezogene [barriers, health-related]. In M. A. Wirtz (Ed.), *Dorsch - Lexikon der Psychologie* (pp. 238). Bern: Huber.

Krämer, L. & Fuchs, R. (2010). Barrieren und Barrierenmanagement im Prozess der Sportteilnahme: Zwei neue Messinstrumente [Barriers and barrier management in physical exercise: introduction of two new assessment instruments]. *Zeitschrift für Gesundheitspsychologie, 18*, 170–182.

Lee, P. H., Macfarlane, D. J., Lam, T. H. & Stuart, S. M. (2011). Validity of the International Physical Activity Questionnaire Short Form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8*(115).

Lopes, V. P., Gabbard, C. & Rodrigues, L. P. (2013). Physical activity in adolescents: examining influence of the best friend dyad. *Journal of Adolescent Health, 52*, 752–756.

Luszczynska, A. & Schwarzer, R. (2003). Planning and self-efficacy in the adoption and maintenance of breast self-examination: A longitudinal study on self-regulatory cognitions. *Psychology and Health, 18*, 93–108.

Metcalf, B., Henley, W. & Wilkin, T. (2012). Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes. *British Medical Journal, 345*(e5888).

Nader, P. R., Bradley, R. H., McRitchie, S. L., Houts, R. M. & O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *Journal of the American Medical Association, 300*, 295–305.

Pate, R. R., Saunders, R. P., O'Neill, J. R. & Dowda, M. (2011). Overcoming barriers to physical activity: helping youth be more active. *ACSM's Health and Fitness Journal, 15*, 7–12.

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Connor Gorber, S. & Tremblay, M. (2008). A comparison of direct versus self-report measures for assessing physical activity in adults: A systematic review. *International Journal of Behavioral and Nutrition and Physical Activity, 5*(56).

Rangul, V., Holmen, T. L., Kurtze, N., Cuyper, K. & Midthjell, K. (2008). Reliability and validity of two frequently used self-administered physical activity questionnaires in adolescents. *BMC Medical Research Methodology*, *8*(47).

Renner, B., Hankonen, N., Ghisletta, P. & Absetz, P. (2012). Dynamic psychological and behavioral changes in the adoption and maintenance of exercise. *Health Psychology, 31*, 306–315.

Sabiston, C. M., O'Loughlin, E., Brunet, J., Chaiton, M., Low, N. C., Barnett, T. et al. (2013). Linking depression symptom trajectories in adolescence to physical activity and team sports participation in young adults. *Preventive Medicine, 56*, 95–98.

Sallis, J. F., Owen, N. & Fisher, E. B. (2008). Ecological models of health behavior. In K. Glanz, B. K. Rimer & K. Viswanath (Eds.), *Health behavior and health education: Theory, research, and practice* (pp. 465–485). San Francisco, CA: Wiley.

Sallis, J. F., Prochaska, J. J. & Taylor, W. C. (2000). A review of correlates of physical activity of children and adolescents. *Medicine & Science in Sports & Exercise, 32*, 963–975.

Satorra, A. & Bentler, P. M. (2001). A scaled difference χ^2 test statistic for moment structure analysis. *Psychometrika, 66*, 507–514.

Sawyer, S. M., Afifi, R. A., Bearinger, L. H., Blakemore, S.-J., Dick, B., Ezeh, A. C. et al. (2012). Adolescence: A foundation for future health. *Lancet, 379*, 1630–1640.

Saxena, R., Borzekowski, D. L. G. & Rickert, V. I. (2002). Physical activity levels among urban adolescent females. *Journal of Pediatric and Adolescent Gynecology, 15*, 279–284.

Scholz, U., Sniehotta, F. F. & Schwarzer, R. (2005). Predicting physical exercise in cardiac rehabilitation: The role of phase-specific self-efficacy beliefs. *Journal of Sport & Exercise Psychology, 27*, 135–151.

Schwarzer, R. (1992). Self-efficacy in the adoption and maintenance of health behaviors: Theoretical approaches and a new model. In R. Schwarzer (Ed.), *Self-efficacy: Thought control of action* (pp. 217–243). Washington, DC: Hemisphere.

Schwarzer, R. (2008). Modeling health behavior change: How to predict and modify the adoption and maintenance of health behaviors. *Applied Psychology: An International Review, 57*, 1–29.

Schwarzer, R., Lippke, S. & Luszczynska, A. (2011). Mechanisms of health behavior change in persons with chronic illness or disability: the Health Action Process Approach (HAPA). *Rehabilitation Psychology, 56*, 161–170.

Schwarzer, R. & Renner, B. (2000). Social-cognitive predictors of health behavior: Action self-efficacy and coping self-efficacy. *Health Psychology, 19*, 487–495.

Sherar, L. B., Gyurcsik, N. C., Humbert, M. L., Dyk, R. F., Fowler-Kerry, S. & Baxter-Jones, A. D. (2009). Activity and barriers in girls (8-16 yr) based on grade and maturity status. *Medicine & Science in Sports & Exercise, 41*, 87–95.

Slater, A. & Tiggemann, M. (2010). "Uncool to do sport": A focus group study of adolescent girls' reasons for withdrawing from physical activity. *Psychology of Sports and Exercise, 11*, 619–626.

Stadler, G., Oettingen, G. & Gollwitzer, P. M. (2009). Physical activity in women: effects of a self-regulation intervention. *American Journal of Preventive Medicine, 36*, 29–34.

Troiano, R. P., Berrigan, D., Mâsse, L. C., Tilert, T. & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise, 40*, 181–188.

Uijtdewilligen, L., Nauta, J., Singh, A. S., van Mechelen, W., Twisk, J. W. R., van der Horst, K. et al. (2011). Determinants of physical activity and sedentary behaviour in young people: a review and quality synthesis of prospective studies. *British Journal of Sports Medicine, 45*, 896–905.

Van der Horst, K., Paw, M. J., Twisk, J. W. & van Mechelen, W. (2007). A brief review on correlates of physical activity and sedentariness in youth. *Medicine & Science in Sports & Exercise, 39*, 1241–1250.

Whitehead, S. & Biddle, S. J. H. (2008). Adolescent girls' perceptions of physical activity: A focus group study. *European Physical Education Review, 14*, 243–262.

Withall, J., Jago, R. & Fox, K. R. (2011). Why some do but most don't. Barriers and enablers to engaging low-income groups in physical activity programmes: A mixed methods study. *BMC Public Health*, *11*(507).

Wong, B. Y., Cerin, E., Ho, S. Y., Mak, K.-K., Lo, W.-S. & Lam, T.-H. (2010). Adolescents' physical activity: competition between perceived neighborhood sport facilities and home media resources. *International Journal of Pediatric Obesity, 5*, 169–176.

World Health Organization. (2010). *Global recommendations on physical activity for health*. Geneva, Swiss: World Health Organization.

Titles of Figures

Figure 1. Seven-factor model of PA barriers.

Note. Digits represent item numbers (boxes), factor loadings (arrows), or latent factor correlations (curves). LEI = leisure activities; LAC = lack of motivation; SCR = screen-based sedentary behavior; DEP = depressed mood; PHY = physical health; SCH = school workload; PRE = preconditions.

* $p < .05$. ** $p < .01$. *** $p < .001$.

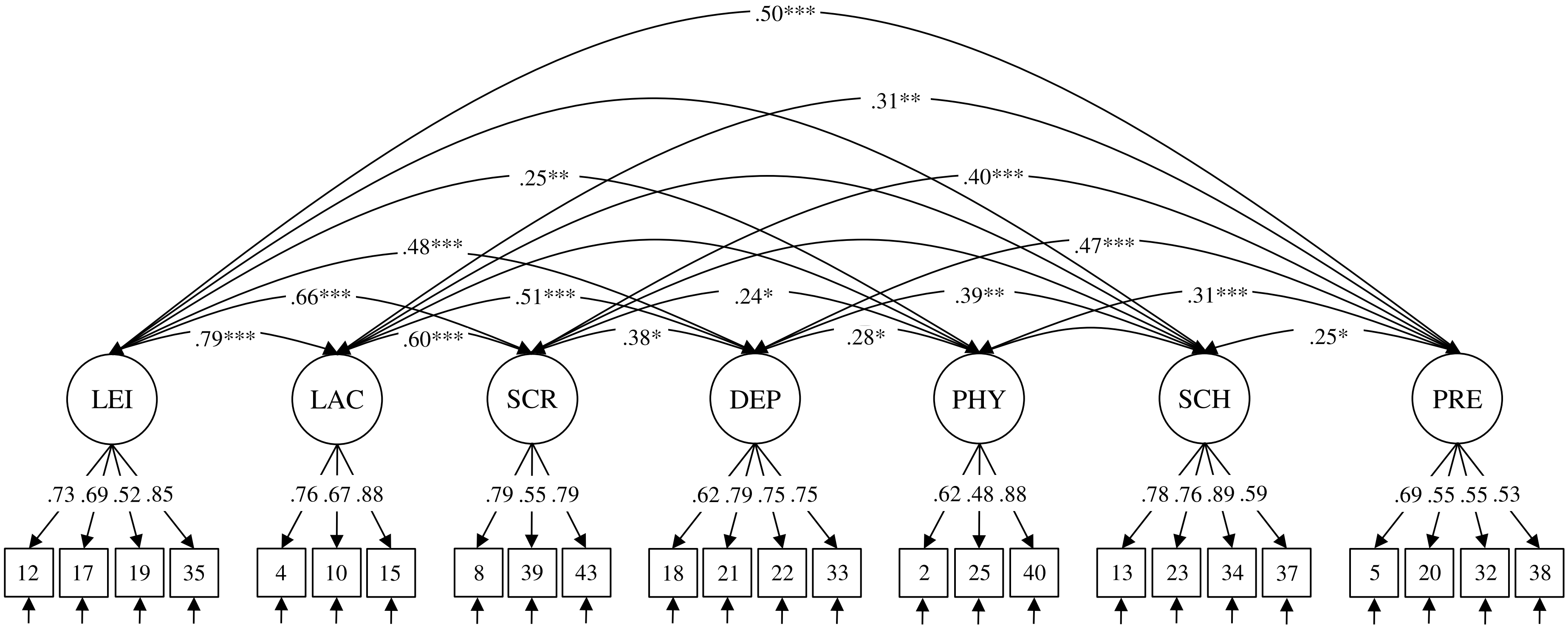
.50***
.31**
.25**
.40***
.48***
.47***
.66***
.51***
.24*
.39**
.31***
.79***
.60***
.38*
.28*
.25*
LEI
LAC
SCR
DEP
PHY
SCH
PRE
.73 .69 .52 .85
.76 .67 .88
.79 .55 .79
.62 .79 .75 .75
.62 .48 .88
.78 .76 .89 .59
.69 .55 .55 .53
12
17
19
35
4
10
15
8
39
43
18
21
22
33
2
25
40
13
23
34
37
5
20
32
38

Table 1

Model Fit in Exploratory Factor Analysis (n = 400)

Factors Extracted	χ^2	*df*	*p*	CFI	RMSEA	90% CI	SRMR
1	4139.06	989	< .001	.55	.09	.09-.09	.09
2	3287.82	944	< .001	.66	.08	. 08-.08	.07
3	2703.20	900	< .001	.74	.07	.07-.07	.06
4	2304.37	857	< .001	.79	.07	.06-.07	.05
5	1919.94	815	< .001	.84	.06	.06-.06	.04
6	1630.96	774	< .001	.88	.05	.05-.06	.04
7	1403.81	734	< .001	.90	.05	.04-.05	.03
8	1243.80	695	< .001	.92	.04	.04-.05	.03

Note. CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual.

Table 2

Standardized Correlations between Barriers, Physical Activity, Intention, Self-Efficacy, and Negative Outcome Expectations (n = 198)

Barriers	WALK	MPA	VPA	MVPA	Intention	Self-efficacy	Negative outcome expectations
LEI	.03	-.12**	-.25**	-.21**	-.43***	-.23*	.50***
LAC	-.07	-.21**	-.33**	-.32**	-.46**	-.36***	.44***
SCR	-.12*	-.09*	-.20**	-.16**	-.39***	-.29**	.29***
DEP	-.01	-.09*	-.16**	-.15**	-.33***	-.29***	.35***
PHY	.02	-.06	-.08	-.08	-.01	-.11	.18**
SCH	-.05	-.06	-.09*	-.08*	.03	-.01	.18**
PRE	-.02	-.01	-.07	-.05	-.22	-.36***	.53***

Note. LEI = leisure activities; LAC = lack of motivation; SCR = screen-based sedentary behavior; DEP = depressed mood; PHY = physical health; SCH = school workload; PRE = preconditions; WALK = walking (min per week); MPA = moderate physical activity (min per week); VPA = vigorous physical activity (min per week); MVPA = moderate-to-vigorous physical activity including walking (min per week).

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3

Results of Item Analysis and Cronbach's Alpha for all Barriers (N = 598)

Barriers	*M* (*SD*)[a]	r_{it}	*p*
Leisure Activities (α = .76)	2.32 (0.82)		
(12) I wanted to do something else on the weekend [Ich wollte am Wochenende etwas anderes machen].	2.50 (1.13)	.56	50
(17) Other hobbies were more important to me [Mir waren andere Hobbies wichtiger].	2.60 (1.05)	.55	32
(19) I preferred to meet my friends [Ich habe mich lieber mit Freunden getroffen].	1.97 (1.04)	.48	53
(35) During leisure time, I rather did something else [Ich habe in meiner Freizeit lieber etwas Anderes gemacht].	2.21 (1.07)	.65	40
Lack of Motivation (α = .77)	2.27 (0.88)		
(4) I did not feel like it [Ich hatte keine Lust].	2.24 (1.07)	.64	41
(10) I was too tired [Ich war zu müde].	2.33 (1.04)	.52	44
(15) I was too lazy [Ich war zu faul].	2.23 (1.07)	.67	41
Screen-Based Sedentary Behavior (α = .76)	1.86 (0.82)		
(8) I preferred surfing the internet [Ich war lieber im Internet].	1.96 (0.99)	.62	32
(39) I rather watched TV [Ich habe lieber Fernsehen geschaut].	1.75 (0.93)	.52	25
(43) I rather played computer games/PlayStation [Ich habe lieber vorm Computer oder der Playstation gesessen].	1.86 (1.04)	.66	29

Continuation of Table 3

Barriers	*M* (*SD*)[a]	r_{it}	*p*
Depressed Mood (α = .84)	1.65 (0.74)		
(18) I felt blue [Ich war deprimiert].	1.47 (0.86)	.65	16
(21) I did a lot of thinking about other things [Ich musste zu viel über andere Dinge nachdenken].	1.93 (0.99)	.66	31
(22) I was in a bad mood [Ich hatte schlechte Laune].	1.72 (0.93)	.73	24
(33) I brooded too much [Ich habe zu viel gegrübelt].	1.44 (0.77)	.70	15
Physical Health (α = .67)	1.53 (0.71)		
(2) I was injured [Ich war verletzt].	1.59 (0.95)	.43	20
(25) I was ill [Ich war krank].	1.57 (0.94)	.47	19
(40) My health status did not allow me to be physically active [Mein Gesundheitszustand hat es nicht erlaubt, mich zu bewegen oder Sport zu machen].	1.43 (0.86)	.57	14
School Workload (α = .83)	1.82 (0.82)		
(13) I had to do too much for school [Ich musste zu viel für die Schule machen].	2.00 (1.04)	.49	34
(23) I had to prepare for papers or exams [Ich musste mich auf Referate oder Arbeiten/Klausuren vorbereiten].	1.63 (0.90)	.71	21
(34) I had too much homework to do [Ich musste zu viele Hausaufgaben machen].	1.94 (1.06)	.69	31
(37) School was over too late [Ich hatte zu lange Unterricht].	1.65 (0.95)	.74	22

Continuation of Table 3

Barriers	M (SD)[a]	r_{it}	p
Preconditions (α = .67)	1.36 (0.54)		
(32) I did not have enough money to be physically active (tickets, membership fee, or workout clothes) [Ich hatte nicht das Geld, um Sport zu machen (Fahrscheine, Vereinsmitgliedschaft, Gebühren, Sportsachen)].	1.28 (0.67)	.42	9
(38) I thought I was not capable to be physically active [Ich habe es mir nicht zugetraut, Sport zu machen].	1.28 (0.70)	.48	9

Note. r_{it} = item discrimination; p = item difficulty.

[a]Scale ranges from 1 (*not at all strong*) to 4 (*very strong*).

Acknowledgements

We thank Giulia Capudi, Magdalena Eich, Hanna Fray, Corinna Jung, Lena Löffler, Laura Loos, Susan Manzke, Verena Noel, Sarah Seitz, and Ebru Sümen for research support. We also wish to express our thanks to Lesley Hernandez, Elizabeth Moulton, and Matthew Riccio for reviewing the manuscript and Lena Krämer for providing feedback on the latest version of the manuscript.

5.2 Appendix B: Manuscript II

Physical Activity, Affect, and Cognition in Children with Symptoms of ADHD

Caterina Gawrilow,[1,2,a] Gertraud Stadler,[3,a] Nadine Langguth,[2] Alexander Naumann,[4] Antje Boeck[5]

[1] Eberhard Karls University Tuebingen, Germany

[2] Center for Research on Education and Human Development DIPF, Germany

[3] Columbia University, USA

[4] Child and Adolescent Psychiatry PK Lüneburg, Germany

[5] University of Hamburg, Germany

[a] Shared First Author

Address correspondence to Caterina Gawrilow: Prof. Dr. Caterina Gawrilow, Eberhard Karls University Tuebingen, Faculty of Science, Department of Psychology, Schleichstr. 4, 72076 Tuebingen, Germany, Telefon +49 7071 29-75627, Telefax +49 7071 29-5902, caterina.gawrilow@uni-tuebingen.de

Abstract

Objective: To examine the role of physical activity in determining the affect and executive functioning of children with symptoms of Attention Deficit Hyperactivity Disorder (ADHD).

Method: In Study 1, the association between physical activity and affect in the daily lives of children with varying degrees of hyperactivity was examined. In Study 2, children with ADHD were randomly assigned a physical activity or a sedentary task before working on a task requiring executive control.

Results: Lack of physical activity was shown to relate to depressed affect, more strongly in participants with severe hyperactivity symptoms (Study 1). The physically active participants showed improved executive functioning after only five min of vigorous activity; the sedentary control participants showed no improvement (Study 2).

Conclusion: These results indicate that interventions to increase the level of physical activity in children with and without ADHD might improve affect and executive functioning.

Keywords: ADHD, physical activity, executive functions, affect

Physical Activity, Affect, and Cognition in Children with Symptoms of ADHD

Deficits in affective and cognitive functioning are common in children with and at risk for Attention Deficit Hyperactivity Disorder (ADHD). In addition to inattentiveness, hyperactivity, and impulsivity, these individuals often suffer from comorbid disorders and, in particular, from affective disorders such as depression (e.g., Blackman, Ostrander, & Herman, 2005; Daviss, 2008; DuPaul, Barkley, & McMurray, 1994). Until now, educational interventions to improve affective and cognitive functioning in children with ADHD symptoms mainly have consisted of token reinforcement systems and positive reinforcement coupled with mild forms of punishment (e.g., response cost systems; DuPaul & Stoner, 2003). Diamond and Lee (2011) discussed several promising intervention approaches that have been shown to improve children's executive functioning including *classroom curricula*, such as Tools of the Mind (Bodrova & Leong, 2007), and *add-ons to classroom curricula*, such as Promoting Alternative Thinking Strategies (PATHS; Kusché & Greenberg, 1994). Both approaches can be implemented by regular teachers in regular classrooms. Another promising approach entails *computerized training programs*. One such program has been found to be effective at improving working memory capacity in children with ADHD (Klingberg et al., 2005); however, the transfer of these programs often is limited (Thorell et al., 2009) and further replication studies are needed desperately (Redick et al., 2012; Shipstead, Redick, & Engle, 2012). Finally, *physical activity interventions* also seem promising in connection with improving children's executive functioning (Diamond & Lee, 2011). For children with and at risk for ADHD in particular, physical activity interventions might be valuable for three reasons: (a) physical activity can be integrated into the everyday routine of a child easily and does not interact negatively with other therapy programs (e.g., medication, cognitive behavioral therapy); (b) physical activity prevents health problems such as weight gain and obesity which are common in children with ADHD (Cortese et al., 2008); and (c) physical activity might improve children's emotional and social functioning in addition to having a positive effect on their cognitive functioning (Ahn & Feweda, 2011; Biddle & Asare, 2011; Dunn & Weintraub, 2008), and so address several problematic areas.

Physical Activity and Psychosocial Functioning in Children

Physical activity is related to improved affect and cognitive functioning in all ages, indeed, the link between physical activity and improved affect is well established and physical activity interventions have been shown to reduce depressive symptoms in healthy adults (Conn, 2010). While there is empirical evidence that children and adolescents accrue mental health benefits from physical activity interventions (e.g., Ahn & Feweda, 2011; Biddle & Asare, 2011; Dunn & Weintraub, 2008), until now, the association between physical activity and depressed affect among children and adolescents, particularly on a daily basis, only has been investigated in a few studies (Dunton, Whalen, Jamner, Henker, & Floro, 2005). A 10-year longitudinal study suggests that during adolescence, changes in leisure-time physical activity and depressed affect are related inversely, that is, decreased levels of physical activity increase the prevalence of depressed affect (Birkeland, Torsheim, & Wold, 2009; Nader, 2009). Furthermore, a meta-analysis of studies investigating the depression- and anxiety-reducing effects of vigorous physical activity interventions in children and adolescents revealed significant effects in favour of the physically active groups (Larun, Nordheim, Ekeland, Hagen, & Heian, 2006). In sum, physical activity predicted lower levels of depressed affect in children and adults in observational studies and randomized controlled trials.

In recent years, researchers have begun to study the link between participation in physical activity and improved cognitive functioning in people without ADHD symptoms. The findings indicate that regular participation in vigorous physical activity improves executive functioning. Intervention studies have demonstrated the positive effects of physical activity on cognitive and affective functions in children without ADHD (Etnier, Nowell, Landers, & Sibley, 2006; Reed & Ones, 2006). Short- and long-term interventions for increasing physical activity have led to improved executive functioning, especially to improved inhibition in children, adolescents, and adults (Barenberg, Berse, & Dutke, 2011; Best, 2010; Colcombe & Kramer, 2003). Consequently, physical activity could be an important additional treatment option for children with ADHD symptoms, ameliorating both comorbid affective disorders and deficits in executive functioning.

For children and adolescents with symptoms of ADHD, research on the cognitive and affective effects of physical activity is still rare. Until recently, only a few observational, single-case, and unpublished studies have reported improved attention and less severe hyperactivity symptoms in children with ADHD following physical activity sessions (Gapin, Labban, & Etnier, 2011; Verret, Guay, Berthiaume, Gardiner, & Béliveau, 2012). In the past, systematic research investigating the potential benefits of physical activity found it to have positive effects on cognitive and affective symptoms associated with ADHD (Gapin & Etnier, 2008; Gapin et al., 2011). Medina and colleagues (2010) examined the impact running on a treadmill for 30 min had on boys diagnosed with ADHD and found that physical activity improved sustained attention, irrespective of medication use. More specifically, response times and vigilance improved while impulsivity decreased. Gapin and Etnier (2010) found that a higher level of physical activity (measured by accelerometers) was associated with better executive function performance in 18 boys with ADHD. Moderate and vigorous physical activity predicted performance on the Tower of London planning task and is associated positively with other measures of executive functioning. In a randomized study, Verret and colleagues (2012) tested the effects of a moderate- to high-intensity physical activity program on fitness, cognitive functioning, and ADHD symptoms over 10 weeks in 21 children diagnosed with ADHD. Children in the treatment group showed better information processing, and parents reported fewer attention issues and a lower total number of problems at follow-up than at baseline compared to children in the control group.

ADHD and depression are common co-morbidities in youths (Biederman et al., 2008). Three studies have addressed the effects of physical activity on affective symptoms. Jensen and Kenny (2004) randomly assigned boys with ADHD who were stabilized on medication to a 20-session yoga condition or a control condition with cooperative activities. Children in both conditions showed improvement in hyperactive and impulsive behaviors and in the global Diagnostic and Statistical Manual of Mental Disorders (DSM) evaluation of ADHD. Yoga decreased oppositional, restless, and impulsive behavior, and the children in the yoga group who engaged in more home practice showed greater improvement in attention and emotional stability. Kiluk, Weden, and Culotta (2009) found that participation in physical activity predicted less severe anxiety and depression in children with ADHD. Scores on parent-reported measures of affect and behavior indicated that children with ADHD who participated in three or more sports displayed fewer symptoms of anxiety and depression than those who participated in fewer than three sports. Verret and colleagues (2012) found in their randomized experiment testing a 10-week physical activity program that teachers reported lower anxiety-depression scores and fewer social problems among children in the treatment group. In summary, physical activity interventions appear to improve cognitive functioning and affect according to test performance, self-reports, and parental and teacher ratings of children with and without ADHD symptoms. Thus, it is important to investigate the effects of everyday physical activity and brief activity interventions on children without symptoms of ADHD as well as on children with symptoms of ADHD to gain insight into the usefulness of physical activity to children with symptoms of ADHD.

Overview of Present Studies

In the present studies we examined the effects of physical activity on children and adolescents at risk for developing or with ADHD: In the first study we investigated whether children with symptoms of hyperactivity show improved affect when they are physically active on a daily basis (i.e., 9-day pedometer data); and in the second study we investigated whether intense bouts of physical activity (i.e., 5-min physical activity interventions) improved executive functioning (i.e., inhibition) in children diagnosed with ADHD.

The studies address the important question of whether children with self-regulatory deficits (as manifested in ADHD symptoms) can improve their affective and cognitive functioning through physical activity. In both studies we analyzed the effect of physical activity in a fine-grained way: In Study 1, we examined the association of physical activity and depressed affect in the daily lives of children with varying degrees of hyperactivity; and in Study 2, an experimental study, we investigated the effects of a short-term physical activity intervention on executive functioning in children diagnosed with ADHD. Both studies were approved by the local ethics committees.

Study 1: Physical Activity and Depressed Affect in Everyday Life

Compared to studies of adults (e.g., Teychenne et al., 2008), studies in which the associations between physical activity and depressed affect among children and adolescents are investigated, particularly on a daily basis (Dunton, Whalen, Jamner, Henker, & Floro, 2005), still are rare; however, studying daily physical activity is central to the examination of short-term variations and interrelations between adolescents' levels of physical activity and depressed affect. We studied the link between daily physical activity and depressed affect in adolescents within and between persons in Study 1, and assumed this link would be stronger in adolescents with more severe hyperactivity. We expected typical participants to show less depressed affect on days when they had a higher than usual amount of physical activity than on days when they had a lower than usual amount of physical activity (Hypothesis 1a: within-person association) and that this within-person activity-affect link would be stronger in participants with more severe hyperactivity (Hypothesis 1b: hyperactivity as moderator of the within-person association). For Hypothesis 2, we tested the association of physical activity and depressed affect between persons. We expected that adolescents who were more physically active would show less depressed affect than adolescents who were less physically active (Hypothesis 2a: between-person association) and that this between-person activity-affect link would be stronger in participants with more severe hyperactivity (Hypothesis 2b: hyperactivity as moderator of the between-person association).

Method

Design. The study had an intensive longitudinal diary design. Participants wore pedometers and reported their current affect in the evening in daily diaries for 10 consecutive days.

Participants and background variables. The sample consisted of 38 adolescents (52.6% female; age: M = 14.4 years). All participants attended German comprehensive schools, were Caucasian, and had a predominantly middle-class background. One in six participants (15.6%) met criteria for elevated depression (German CES-D short version, Hautzinger & Bailer, 1993; Meyer & Hautzinger, 2001; cut-off values based on Lehr, Hillert, Schmitz, & Sosnowsky, 2008). Table 1 provides an overview of participant characteristics.

Procedure. Between April and May 2009, adolescents from comprehensive schools (Grades 5 to 10) in a large city in Germany were invited by letter to participate. The study was described as an examination of adolescents' leisure-time behavior, physical activity, and well-being. Adolescents were informed that their data would remain confidential and that their participation was voluntary and would not affect their school grades. The letter stated that all adolescents were welcome to participate regardless of their current level of physical activity. Adolescents with chronic health conditions that would require medically supervised physical activity were not included. To participate in the study, adolescents and their parents were required to give informed consent and indicate their preference for completing the questionnaire and daily diary components of the study online or in paper-and-pencil form. All data were collected between June and August 2009.

On the first day of the study, researchers went to comprehensive schools and measured participants' stride length to ensure step counts would be recorded correctly. In small groups, participants were shown how to wear their pedometers and were encouraged to be physically active as usual. Subsequently, participants were given 30 min to familiarize themselves with their pedometers and to take a short walking test. The majority of participants chose the online format (*n* = 24) and were given a link to the background questionnaire and an e-mail link to the diaries daily at 8.00 p.m. Adolescents who had chosen the paper-and-pencil format (*n* = 14) were given one background questionnaire and 10 daily diaries. Regardless of the format, all participants were asked to complete their diaries each day no earlier than one hour before going to bed. At the beginning of the study, participants completed a background questionnaire (e.g., general mental health, depressive symptoms). After taking part in the study for at least five consecutive days, participants received €10 ($14.30).

Measures.

Daily depressed affect. Participants reported their current depressed affect in their daily diaries using a five-point scale ranging from 1 (*not at all*) to 5 (*extremely*) on three items: "sad," "depressed," "distressed." Daily composite scores were computed by averaging the appropriate item scores. Following a generalizability theory approach (Cranford et al., 2006; Cronbach, Gleser, Nanda, & Rajaratnam, 1972), we calculated the between-person reliability for average depression over nine diary days (Day 2 to Day 10), $R_{KF} = .94$, and the reliability of day-to-day changes in depression, $R_C = .72$.

Physical activity. Daily physical activity was measured using a commercially available, piezoelectric pedometer, the OMRON Walking Style II (HJ-113; OMRON Healthcare, Mannheim, Germany). The OMRON HJ-113 uses a biaxial acceleration sensor placed either horizontally or vertically to count the user's steps accurately, independent of speed (Giannakidou et al., 2012). Compared to spring-levered pedometers, piezoelectric pedometers such as the OMRON HJ-112/113 are considered to be more precise at measuring the step counts of children (Nakae, Oshima, & Ishii, 2008). Pedometers are used widely and are among the most appropriate devices to monitor physical activity in children and adolescents, particularly under real-life conditions (Tudor-Locke, McClain, Hart, Sisson, & Washington, 2009). Furthermore, even for very young children there is evidence that pedometers are a reliable and valid device for measuring free play and general physical activity (Hands, Larkin, Parker, Straker, & Perry, 2009).

An OMRON HJ-113 was attached (according to the manufacturer's guidelines) to each participant's waistband above the right hipbone. Participants were able to see their daily step counts. They were instructed to wear the pedometer for 10 consecutive days except when they were sleeping or during water-based activities (e.g., swimming, taking a shower). The pedometer used in this study does not record wear time so participants were asked to report in their daily diaries what time they went to bed, what time they got up, and periods when they did not wear the pedometer (e.g., "Today, I was swimming from 3:15 p.m. to 4:45 p.m."). The average time per day participants spent in bed was 9.52 hours and the average time spent wearing their pedometers was 13.03 hours. Daily step counts were reset automatically at midnight and stored for eight consecutive days. On the eighth day, researchers wrote down the step counts of the participants for the previous seven days. Afterwards, pedometers were handed out again and participants were instructed to wear them for another three days. One day after the end of the study, researchers collected the completed paper-and-pencil records and pedometers at the school and recorded participants' step counts for the last three days of the study. Physical activity (i.e., the number of steps taken each day) was divided by 10,000 to allow regression results to be displayed to two decimals.

Hyperactivity. Hyperactivity was assessed using a single item from the self-report form of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997): Participants rated "I constantly fidget or squirm" on a three-point scale ranging from 0 (*not true*) to 2 (*certainly true*). The SDQ is used frequently as a screening instrument for mental health issues among children and adolescents (Woerner et al., 2004); its Prosocial Behavior subscale measures psychological adjustment and its other four subscales, Emotional Problems, Conduct Problems, Hyperactivity/Inattention, and Peer Problems, measure psychopathology in children and adolescents aged 11 to 17 years. The SDQ contains 25 items and has proven to be a valid instrument (for the UK version, Goodman, Metzer, & Bailey, 1998; for the German version, Klasen et al., 2000). For the German SDQ self-reporting measure, Becker, Hagenberg, Roessner, Woerner, and Rothenberger (2004) replicated the five-factor solution previously proposed by Goodman (1997). Klasen and colleagues (2000) and Goodman (2001) showed that the SDQ differentiates between children with and without ADHD symptoms. The SDQ's Hyperactivity/Inattention subscale is heterogeneous, as its name implies; therefore, we decided to focus on the item that best reflects the core symptom of hyperactivity.

Data analysis. Data were analyzed with SAS (SAS Institute Inc., 2011). Day refers to the study day as coded Day 1 through Day 10 and centered at Day 2 (Dayc2). Days 2 to 10 were used for these analyses to allow participants one initial day to familiarize themselves with the diary protocol. Time is an important component of the model because it can influence both predictors and outcomes and can lead to a spurious relationship between the two (Bolger & Laurenceau, in press). Hyperactivity was centered at the grand mean in this sample (M = 0.63). Physical activity varied both within and between persons, therefore, the variable steps were split into two predictor variables: (a) $StepsB_i$, the between-person mean steps across all diary days for each individual i; and (b) $StepsW_{it}$, the within-person deviations from each person's mean steps for each individual i at time t. $StepsBc_i$, a centered version of $StepsB_i$, was created by subtracting the grand mean in the sample from $StepsB_i$.

Equation 1 represents a composite multilevel regression to test Hypotheses 1 and 2.

$$Depr_{it} = (\gamma_{00} + u_{0i}) + (\gamma_{10} + u_{1i})Dayc5_{it} + \gamma_{01}Hyperc_i + \gamma_{11}StepsW_{it} + \gamma_{12}StepsW_{it} \text{ x } Hyperc_i + \gamma_{02}StepsBc_i + \gamma_{03}StepsBc_i \text{ x } Hyperc_i + \varepsilon_{it} \quad (1)$$

The model in Equation 1 tests whether the following seven fixed effects are different from 0: (a) the intercept for depressed affect, γ_{00}; (b) the average slope for time, γ_{10}, indicating the change in depressed affect over the days of the study; (c) the between-person association of hyperactivity and depressed affect, γ_{01}, indicating the change in depressed affect with a unit increase in hyperactivity; (d) the average within-person association of steps and depressed affect, γ_{11}, indicating the change in depressed affect with each unit increase in steps per day over the participant's usual level; (e) the moderation of the within-person physical activity-affect link by hyperactivity, γ_{12}; (f) the between-person association of steps and depressed affect, γ_{02}, indicating the association of between-person differences in physical activity with depressed affect; and (g) the moderation of the between-person link between physical activity and affect by hyperactivity, γ_{03}. The model also includes two random effects: the first, u_{0i}, indicates the shift from the average intercept γ_{00} for a particular person; and the second, u_{1i}, indicates the shift from the average time slope γ_{10} for a particular person.

Results

Consistent with Hypothesis 1, the findings from Study 1 show a moderate within-person link between participation in physical activity and affect (Table 2). Typically, participants showed less depressed affect on days when they engaged in a higher-than-usual amount of physical activity than on days when they engaged in a lower-than-usual amount of physical activity, and this within-person physical activity-affect link was stronger in participants with more severe hyperactivity (Figure 1). For the typical participant, depressed affect decreased by 0.29 on a given day with a 1-unit increase in physical activity (10,000 steps) over the person mean in physical activity. With a 1-unit increase in hyperactivity, depression decreased an additional 0.38. The data did not support Hypothesis 2–that there would be a moderate between-person link between physical activity and affect: Participants who typically were more physically active did not show less depressed affect than adolescents who were less physically active, and hyperactivity did not moderate this link.

In this sample, higher hyperactivity was related to higher level of depressive symptoms at baseline (measured with the CES-D: $r = .25$), in line with prior studies finding that depression is a common comorbid condition for children at risk and diagnosed with

ADHD (Blackman et al., 2005; Daviss, 2008; DuPaul et al., 1994). In sensitivity analyses, we tested if the stronger link between physical activity and depressed mood in adolescents with higher hyperactivity was due to their higher baseline level of depression. Adding baseline depressive symptoms to the multilevel model did not change the pattern of results.

Discussion

Physical activity and affect were linked within person, and more strongly in the hyperactive adolescents who comprised in this sample. Daily deviations from their typical physical activity levels were linked with negative affect. Adolescents who were more physically active than usual in the daytime showed less depressed affect in the evening. The physical activity-affect link was stronger for adolescents with more severe hyperactivity. Given that the items used to assess depressed affect were designed to capture more intense depressed affect (using the adjectives “sad,” “depressed,” “distressed”) and were thus difficult to endorse even low levels of endorsement seem relevant. On average, participants reported depressed affect of 1.44 on a 1 to 5 scale with higher values indicating higher depressed affect. The difference between days with higher-than-usual physical activity, compared to days with lower-than-usual physical activity, would amount to adolescents with hyperactivity reporting that they were not at all depressed versus a little depressed.

Three processes could explain these findings. First, intense physical activity could have beneficial effects on affect within a day. Some prior experiments and intervention studies already have provided evidence for this causal process (Ahn & Feweda, 2011; Conn, 2010; Dunn & Weintraub, 2008; Dunton et al., 2005). The current study indicates that this process may occur naturally and without the context of a structured, possibly costly, and artificial intervention. Second, negative affect could lead to a decrease in physical activity, creating a daily downwards spiral of negative affect and behavioral inactivation. This second physical activity-to-affect pathway could operate in addition to the first process. Third, another variable that co-occurs in time could cause both physical activity and affect fluctuations. Additional research with more fine-grained daily measures will be necessary to determine the effect size of these pathways. Our findings encourage further research and indicate that children and adolescents may benefit from physical activity interventions to regulate their affect.

Study 1 has several limitations. First, the participants' hyperactivity was measured using ratings from a screening questionnaire rather than through examination by a trained professional; however, grouping children and adolescents at risk and not at risk of ADHD on the basis of indications from parents is a commonly used, valid, and reliable approach (Döpfner et al., 2006). We can assume that the participants experienced symptoms of hyperactivity even though we cannot be sure that they would receive a full-scale diagnosis of ADHD. Hyperactivity may predispose individuals to experience more benefits from physical activity. Additional research is necessary to see if the effects of physical activity generalize to individuals who predominantly show the other key symptoms of ADHD–inattentiveness and impulsivity. A second limitation is in the use of the paper-and-pencil format by 14 participants. The online format chosen by most participants has the advantage that each diary entry has a time stamp; this encourages participants to fill out diaries on time. However, some of the participants did not have adequate Internet access at home at the time of the study and/or were not allowed to use the Internet before bedtime so we decided to offer a paper-and-pencil version and an online version of the daily diaries to include those adolescents in Study 1. Both formats appear to provide psychometrically and statistically equivalent data (Green, Rafaeli, Bolger, & Shrout, 2006). Third, the current study had a limited sample size. There were no prior published studies that would provide starting points for an a-priori power analysis (Bolger, Stadler, & Laurenceau, 2012). We calculated post-hoc power and found that power to detect three out of four effects of interest exceeded .80 (Physical Activity, Within-Person; Physical Activity, Within-Person x Hyperactivity; Physical Activity, Between-Person x Hyperactivity). The found effect size for the between-person association of physical activity and depressed affect was close to 0. If this effect is true in the population, much larger studies would not be able to detect it. Therefore, we expect that studies with larger sample sizes would be able to replicate our finding that on days with higher-than-usual physical activity adolescents are less depressed, and that this effect is stronger for adolescents with the ADHD symptom hyperactivity. Furthermore, the study with its limited sample size was not designed to investigate additional moderation and mediation processes. For example, the social aspects of physical activity would be interesting to examine (Brunet et al., 2013; Salvy et al., 2008). It is not clear if physical activity alone, with others, or in athletic teams has different effects on mood, and if these social aspects interact with hyperactivity in daily life. Future studies should be designed with adequate power and measures to examine these processes.

Study 2: Effects of a Brief Physical Activity Intervention on Executive Functioning in Children with ADHD

In Study 2, we were interested in the effects of a single bout of physical activity on cognitive functioning in children with ADHD. To simulate tasks requiring attention such as learning in the classroom, participants took a difficult attention test to deplete their executive functioning before being randomly assigned to either perform a physical activity or a sedentary task before working on a task requiring the use of executive functions. We hypothesized that the participants who were assigned five min of vigorous physical activity would show improved executive control (i.e., improved response inhibition in an inhibition task) and that the participants in the sedentary control condition would show no improvement.

Method

Participants and background variables. Participants were recruited from a psychiatric clinic (Child and Adolescent Psychiatry PK Lüneburg, Germany) and had been diagnosed with Hyperkinetic Disorder F90.0 (ICD-10; World Health Organization, WHO, 1991) as their primary disorder. Because ADHD is much more prevalent in boys than in girls, the recruitment clinic treats mostly boys. Thus, we limited the sample to males. With regard to ethnic background, all of the participants with ADHD were Caucasian. Boys (N = 47) aged between 8.3 and 13.6 years (M = 10.47, SD = 1.49) participated in this experimental study only after they and their parents gave informed consent. At the time of the study, 33 of the participants (70.2%) were being treated with methylphenidate (MPH) and 28 (59.5%) were being treated with cognitive behavioral therapy (CBT).

Diagnostic procedure. All participants were diagnosed with ADHD according to a standard protocol used in the psychiatric clinic (e.g., interviews, questionnaires, standardized tests of intelligence and attention). Parents were asked to fill out the ADHD questionnaire taken from the Diagnostic System for Psychiatric Disorders in Childhood (DISYPS-KJ, Döpfner & Lehmkuhl, 2000), the Child Behavior Checklist for children aged 4 to 18 (CBCL; Arbeitsgruppe Deutsche Child Behavior Checklist, 1998) and the Conners Scale (Conners, 2008) to verify the ADHD diagnosis and/or other psychological problems. These questionnaires allow hyperkinetic disorders and ADHD to be evaluated on the basis of the ICD-10 (WHO, 1991) or DSM-IV criteria (APA, 2000) with the assessment of the ADHD core symptoms (inattentiveness, hyperactivity-impulsivity). Furthermore, the participants were given an intelligence test (i.e., either K-ABC from Melchers & Preuss, 2001 or HAWIK-IV from Petermann & Petermann, 2007) as well as a standardized attention test (TAP, Test of Attentional Performance; Zimmermann & Fimm, 2006). Only children who met ICD-10 criteria for ADHD on these measures were included in the study.

Procedure. A female experimenter guided participants through the procedure and was present during the performance of all tasks. Participants first completed a 6-min computerized attention task (FAKT-II, Moosbrugger & Goldhammer, 2007). They were asked to discriminate between two very similar items (e.g., circle with two or with three dots); the length of the presentation time of the stimuli varied according to the individual response time and error rate of each participant to ensure adaptive testing. Prior to the actual test, participants did 20 practice trials to get used to the task.

Participants then randomly were assigned to one of two conditions: performing a physical activity; or performing a sedentary task. In the physical activity condition, participants were asked to jump on a trampoline for five min. The female experimenter asked each of the participants to jump continuously for five min to standardize the intensity level of the exercise. Using a standard protocol, the experimenter asked the participants to start jumping again if they stopped before five min had elapsed. Participants in the sedentary condition were asked to spend five min coloring in pictures depicting activities. They were informed that they would be allowed to take the pictures home to prevent them from feeling pressure to be neat and finish quickly.

After their sedentary or active task, participants worked on a classification task combined with a Go/NoGo task for 21 min (Gawrilow & Gollwitzer, 2008). The classification task stimuli contained pictures of animals (chicken, cat, mouse, cow, pig) and pictures of means of transportation (plane, car, truck, ship, train). Specifically, one of the five different means of transportation or one of the five different animals was presented on a 15-inch computer screen. The task called for participants to classify stimuli by pressing a particular computer key (classification task, Go trials) and also to inhibit classification in response to a stop signal (200-Hz sound, No-Go trials). Each stimulus was preceded by a 500-ms fixation cross presented in the center of the screen. Either an animal or a means of transportation was presented in the center of the screen for 1,000 ms. Thereafter, a blank screen appeared for 1,500 ms. Participants classified the presented stimuli as either an animal or a means of transportation by pressing one of two marked keys on the keyboard with the index finger of their left or right hand, respectively. One-third of the time, stop signals were presented 150 ms before the appearance of the stimulus. The computer key assignment was switched during the experiment to make the task more difficult and to counterbalance the keys. We measured both the number of successful stops on the No-Go trials and the response times for the Go trials as dependent variables. After this task we measured perceived commitment and task difficulty (e.g., "I worked hard on the task," or "I found the task difficult").

Results

As predicted, participants in the physical activity condition showed significantly more successful response inhibition (*M* = 76.83, *SD* = 21.68) than those in the sedentary condition (*M* = 65.54, *SD* = 30.10), $t(45) = 1.46$, $p < .05$. Errors on Go-trials showed the same pattern (commission and omission errors in the complete task): participants in the physical activity condition made significantly fewer errors (*M* = 32.78, *SD* = 26.61) than those in the sedentary condition (*M* = 46.08, *SD* = 35.28), $t(45) = 1.45$, $p < .05$. Interestingly, there were no significant differences in perceived commitment and task difficulty between participants in both conditions, all *p*s > .13.

Discussion

The results of Study 2 indicate that a very brief bout of vigorous physical activity (5-min physical activity intervention) but not performing a sedentary task led to better response inhibition and fewer errors on a sustained attention task in children with diagnosed ADHD. Thus, the findings support the notion that individuals with ADHD can benefit from engaging in physical activity. However, the study has several limitations. First, boys are diagnosed with ADHD much more frequently than girls: The study hence addressed the largest patient segment and investigated the effects of a brief physical intervention in boys diagnosed with ADHD. Second, the current study did not include a comparison group of matched controls without ADHD. Based on previous findings, we would expect similar cognitive benefits would also be found in children without ADHD. Thus, further studies might want to include girls with ADHD and children without ADHD to find out whether the effects of such an intervention generalize to girls diagnosed with ADHD and to children without ADHD. A third limitation of Study 2 is the fact that many children were taking psychostimulant medication at the time of investigation. However, the fact that we showed effects above and beyond the medication is important. Although Medina and colleagues (2010) already showed that the positive influence of physical activity on executive functioning in children with ADHD is independent of the effects of medication, further studies are needed for clarification. Even though medication is by far the most effective treatment for ADHD, some children do not respond to it (e.g., DuPaul et al., 1994). Thus, research is needed to address the issues of whether children who do not respond to medication do respond to physical activity, whether physical activity is a helpful additional treatment for children who do respond to medication, and whether engaging in physical activity would allow children to reduce the dosage of their medication (Gapin & Etnier, 2010). Fourth, our study did not investigate long-term effects and it is therefore still questionable whether children with ADHD would benefit from brief bouts of physical activity in their everyday life and over longer time frames. Lastly, the large variability (i.e., high standard deviations of response inhibition) could point to the fact that our activity manipulation has better effects in some ADHD patients than in others (i.e., heterogeneity in ADHD; Wahlstedt, Thorell, & Bohlin, 2009). The current study was not designed to investigate moderators but future studies with larger samples should include moderators (e.g., ADHD symptom severity, comorbities such as depression, children's current fitness level, Moore et al., 2013).

General Discussion

The studies showed that physical activity can benefit both children at risk for ADHD and children diagnosed with ADHD. Study 1 tested the association between physical activity and affect in daily life in children with varying degrees of hyperactivity symptoms. Physical activity was related to depressed affect within person, and this association was stronger in children with more severe hyperactivity. Furthermore, and as hypothesized, Study 2 demonstrated that a brief activity intervention was able to improve performance on a Go/NoGo task in children with ADHD.

Implications for Research on ADHD Interventions

The results of our studies indicate that physical activity interventions should be encouraged for the treatment of affective and cognitive symptoms in children with ADHD. Although until recently few studies have addressed this issue, this initial evidence indicates that physical activity can lead to improved attention and decreased hyperactivity in children with ADHD (e.g., Gapin & Etnier, 2010). Various types of physical activity have positive effects on a number of symptoms associated with ADHD (Gapin & Etnier, 2008; Gapin et al., 2011); for example, physical activity appears to improve adolescents' self-esteem (e.g., Biddle & Asare, 2011), self-efficacy (e.g., Dishman, Dunn, Sallis, Vandenberg, & Pratt, 2010), emotional well-being (i.e., depression and anxiety; Larun et al., 2006), and provides good opportunities for socializing with peers (e.g., Salvy et al., 2007). Social benefits seem to be particularly important to adolescents with ADHD, who often experience problematic peer relationships (e.g., Murray-Close et al., 2010). For children and adolescents with comorbid ADHD and obesity (Cortese et al., 2008), physical activity programs that encourage an active lifestyle could also improve their overall physical health (Pagoto, Curtin, Appelhans, & Alonso-Alonso, 2012). Both studies indicate that interventions leading to more physical activity might be promising additions to existing ADHD treatment programs (e.g., CBT, MPH). Researchers conducting further intervention studies may want to investigate long-term randomized controlled trials in larger samples of children with and without ADHD. Moreover, further studies should investigate possible mechanisms that lead to positive effects of physical activity interventions in those children.

Conclusion

In the studies presented in this article, either physical activity fluctuations in daily life or manipulated short-term physical activity were assessed. The results of both studies encourage further testing of physical activity as a cost- and time-efficient way to improve executive functioning and affect in children and adolescents with ADHD. In addition to improved cognitive and affective functioning, physical activity has shown many more benefits in other samples, including improvement in self-concept, general well-being, and the quality of interpersonal relationships. Further studies are needed to examine the benefits of physical activity in a more comprehensive way. As in adults, the ideal frequency and the dose of physical activity are still to be determined. The conditions under which physical activity can be initiated and maintained over longer periods of time also should be investigated in future research. Taken together, physical activity is a promising candidate for alleviating common symptoms in children and adolescents with ADHD.

Bios

Caterina Gawrilow, PhD, is a Professor of school psychology at the Eberhard Karls University in Tuebingen and at the DIPF, Frankfurt. Currently, her main areas of interest are (i) ADHD in children and adolescents, (ii) experimental and applied research on self-regulation and executive functioning, and (iii) gene X environment analysis.

Gertraud Stadler, PhD, is an Associate Research Scientist at the Mailman School of Public Health and the Psychology Department at Columbia University. Her main research interest is on individual and social regulation of behavior change. This interest has led her to learn a great deal about quantitative methods including intensive longitudinal designs and measurement using diaries, physiological indicators and sensors, and about the analysis of longitudinal data.

Nadine Langguth is a doctoral student at the DIPF and the Goethe University of Frankfurt. Her primary research interest is on the associations among sensor-based physical activity, affect, and cognition within an intensive longitudinal approach.

Alexander Naumann, MD, is head of the department of Child and Adolescent Psychiatry and Psychotherapy at the Psychiatric Hospital Lüneburg. His main working fields are evidence-based child and adolescent psychotherapy and psychiatry, implementing clinical guidelines in day-to-day clinical practice as well as health services research in child and adolescent psychiatry and psychotherapy.

Antje Boeck works as a school psychologist in Hamburg. Additionally, she is attending a further education program at the Peter-Riedesser-Institut in Hamburg. Her main interests are the association between motor and cognitive development in children and adolescents and the training of teachers.

References

Ahn, S., & Feweda, A. L. (2011). A meta-analysis of the relationship between children's physical activity and mental health. *Journal of Pediatric Psychology, 36*, 385–397. doi:10.1093/jpepsy/jsq107

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: American Psychiatric Association. doi:10.1176/appi.books.9780890423349

Arbeitsgruppe Deutsche Child Behavior Checklist. (1998). *Elternfragebogen über das Verhalten von Kindern und Jugendlichen. Deutsche Bearbeitung der Child Behavior Checklist (CBCL/4-18)* [German consensus version of the Child Behavior Checklist (CBCL/4-18)]. Köln, Germany: Arbeitsgruppe Kinder-, Jugend- und Familiendiagnostik (KJFD).

Barenberg, J., Berse, T., & Dutke, S. (2011). Executive functions in learning processes: Do they benefit from physical activity? *Educational Research Review, 6*, 208–222. doi:10.1016/j.edurev.2011.04.002

Becker, A., Hagenberg, N., Roessner, V., Woerner, W., & Rothenberger, A. (2004). Evaluation of the self-reported SDQ in a clinical setting: Do self-reports tell us more than ratings by adult informants? *European Child & Adolescent Psychiatry, 13*(Suppl. 2), 17–24. doi:10.1007/s00787-004-2004-4

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30*, 331–351. doi:10.1016/j.dr.2010.08.001

Biddle, S. J. H. & Asare, M. (2011). Physical activity and mental health in children and adolescents: a review of reviews. *British Journal of Sports Medicine, 45*, 886–895. doi:10.1136/886 bjsports-2011-090185

Biederman, J., Ball, S. W., Monuteaux, M. C., Mick, E., Spencer, T. J., McCreary, M., … Faraone, S.V. (2008). New insights into the comorbidity between ADHD and major depression in adolescent and young adult females. *Journal of the American Academy of Child and Adolescent Psychiatry, 47*, 426–434. doi:10.1097/CHI.0b013e31816429d3

Birkeland, M. S., Torsheim, T., & Wold, B. (2009). A longitudinal study of the relationship between leisure-time physical activity and depressed mood among adolescents. *Psychology of Sport and Exercise, 10*, 25–34. doi:10.1016/j.psychsport.2008.01.005

Blackman, G. L., Ostrander, R., & Herman, K. C. (2005). Children with ADHD and depression: A multisource, multimethod assessment of clinical, social, and academic functioning. *Journal of Attention Disorders, 8*, 195–207. doi:10.1177/1087054705278777

Bodrova, E., & Leong, D. J. (2007). *Tools of the mind* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Bolger, N., & Laurenceau, J. P. (in press). *Diary methods*. New York, NY: Guilford.

Brunet, J., Sabiston, C. M., Chaiton, M., Barnett, T. A., O'Loughlin, E., Low, N. C. P., & O'Loughlin, J. L. (2013). The association between past and current physical activity and depressive symptoms in young adults: a 10-year prospective study. *Annals of Epidemiology, 23*, 25–30.

Colcombe, S., & Kramer, A. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14*, 125–130. doi:10.1111/1467-9280.t01-1-01430

Conn, V. S. (2010). Depressive Symptom outcomes of physical activity interventions: Meta-analysis findings. *Annals of Behavioral Medicine, 39*, 128–138. doi:10.1007/s12160-010-9172-x

Conners, C. K. (2008). *Conners 3rd Edition™*. Toronto, Canada: Multi-Health Systems.

Cortese, S., Angriman, M., Maffeis, C., Isnard, P., Konofal, E., Lecendreux, M., … Mouren, M. C. (2008). Attention-deficit/hyperactivity disorder (ADHD) and obesity: a systematic review of the literature. Critical Reviews in Food Science and Nutrition, 48, 524–537. doi: 10.1080/10408390701540124

Cranford, J. A., Shrout, P. E., Iida, M., Rafaeli, E., Yip, T., & Bolger, N. (2006). A procedure for evaluating sensitivity to within-person change: Can mood measures in diary studies detect change reliably? *Personality and Social Psychology Bulletin, 32*, 917–929. doi:10.1177/0146167206287721

Cronbach, L. J., Gleser, G. C., Nanda, H., & Rajaratnam, N. (1972). *The dependability of behavioral measurements: Theory of generalizability for scores and profiles*. New York, NY: Wiley.

Daviss, W. (2008). A review of co-morbid depression in pediatric ADHD: Etiologies, phenomenology, and treatment. *Journal of Child and Adolescent Psychopharmacology, 18*, 565–571. doi:10.1089/cap.2008.032

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4-12 years old. *Science, 333*, 959–964. doi:10.1126/science.1204529

Dishman, R. K., Dunn, A. L., Sallis, J. F., Vandenberg, R. J., & Pratt, C. A. (2010). Social-cognitive correlates of physical activity in a multi-ethnic cohort of middle-school girls: Two-year prospective study. *Journal of Pediatric Psychology, 35*, 188–198. doi:10.1093/jpepsy/jsp042

Döpfner, M., & Lehmkuhl, G. (2000). *Diagnostik-System für psychische Störungen im Kindes- und Jugendalter nach ICD-10 und DSM-IV (DISYPS-KJ)* [Diagnostic System for Mental Disorders in Childhood and Adolescence]. Bern, Swiss: Huber.

Döpfner, M., Lehmkuhl, G., & Steinhausen, H. C. (2006). *KIDS Kinder-Diagnostik-System 1. ADHS* [Children Diagnostic System 1. ADHD]. Göttingen, Germany: Hogrefe.

Dunn, A. L., & Weintraub, P. (2008). Exercise in the prevention and treatment of adolescent depression: A promising but little researched intervention. *American Journal of Lifestyle Medicine, 2*, 1–12. doi:10.1177/1559827608323225

Dunton, G. F., Whalen, C. K., Jamner, L. D., Henker, B., & Floro, J. N. (2005). Using ecologic momentary assessment to measure physical activity during adolescence. *American Journal of Preventive Medicine, 29*, 281–287. doi:10.1016/j.amepre.2005.07.020

DuPaul, G. J., & Stoner, G. (2003). *ADHD in the schools. Assessment and intervention strategies*. New York, NY: Guilford.

DuPaul, G. J., Barkley, R. A., & McMurray, M. B. (1994). Response of children with ADHD to Methylphenidate: Interaction with internalizing symptoms. *Journal of the American Academy of Child and Adolescent Psychiatry, 33,* 894–903. doi: 10.1097/00004583-199407000-00016

Etnier, J. L., Nowell, P. M., Landers, D. M., & Sibley, B. A. (2006). A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Research Reviews, 52*, 119–130. doi:10.1016/j.brainresrev.2006.01.002

Gapin, J. I., & Etnier, J. L. (2008). Relationship between physical activity, behavioral symptoms, and executive function in ADHD children. *Journal of Sport and Exercise Psychology, 30*, S25.

Gapin, J. I., & Etnier, J. L. (2010). The relationship between physical activity and executive function performance in children with attention-deficit hyperactivity disorder. *Journal of Sport and Exercise Psychology, 32*, 753–763.

Gapin, J. I., Labban, J. D., & Etnier, J. L. (2011). The effects of physical activity on attention deficit hyperactivity disorder symptoms: The evidence. *Preventive Medicine, 52*, S70–S74. doi:10.1016/j.ypmed.2011.01.022

Gawrilow, C., & Gollwitzer, P. M. (2008). Implementation intentions facilitate response inhibition in children with ADHD. *Cognitive Therapy and Research, 32*, 261–280. doi:10.1007/s10608-007-9150-1

Giannakidou, D. M., Kambas, A., Ageloussis, N., Fatouros, I., Christoforidis, C., Venetsanou, F., … Taxildaris, K. (2012). The validity of two Omron pedometers during treadmill walking is speed dependent. *European Journal of Applied Physiology, 112*, 49–57. doi:10.1007/s00421-011-1951-y

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A research note. *Journal of Child Psychology and Psychiatry, 38*, 581–586. doi:10.1111/j.1469-7610.1997.tb01545.x

Goodman, R. (2001). Psychometric Properties of the Strengths and Difficulties Questionnaire. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*, 1337–1345. doi:10.1097/00004583-200111000-00015

Goodman, R., Meltzer, H., & Bailey, V. (1998). The Strengths and Difficulties Questionnaire: A pilot study on the validity of the self-report version. *European Child and Adolescent Psychiatry, 7*, 125–130. doi:10.1007/s007870050057

Green, A. S., Rafaeli, E., Bolger, N., & Shrout, P. E. (2006). Paper or plastic? Data equivalence in paper and electronic diaries. *Psychological Methods, 11*, 87–105. doi:10.1037/1082-989X.11.1.87

Hands, B. P., Larkin, D., Parker, H., Straker, L., & Perry, M. (2009). The relationship between physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scandinavian Journal of Medicine & Science in Sports, 19*, 655–663. doi: 10.1111/j.1600-0838.2008.00847.x

Hautzinger, M., & Bailer, M. (1993). *Allgemeine Depressions Skala (ADS)* [Center for Epidemiologic Studies - Depression Scale, CES-D]. Göttingen, Germany: Beltz.

Jensen, P. S., & Kenny, D. T. (2004). The effects of yoga on the attention and behavior of boys with attention-deficit/hyperactivity disorder (ADHD). *Journal of Attention Disorders, 7*, 205–216. doi:10.1177/108705470400700403

Kiluk, B. D., Weden S., & Culotta, V. P. (2009). Sport participation and anxiety in children with ADHD. *Journal of Attention Disorders, 12*, 499–506. doi:10.1177/1087054708320400

Klasen, H., Woerner, W., Wolke, D., Meyer, R., Overmeyer, S., Kaschnitz, W. … Goodman, R. (2000). Comparing the German versions of the Strengths and Difficulties Questionnaire (SDQ-Deu) and the Child Behavior Checklist. *European Child & Adolescent Psychiatry, 9*, 271–276. doi:10.1007/s007870070030

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., … Westerberg, H. (2005). Computerized training of working memory in children with ADHD – a randomized, controlled trial. *Journal of the American Academy of Child & Adolescent Psychiatry, 44*, 177-186. doi:10.1097/00004583-200502000-00010

Kusché, C. A., & Greenberg, M. T. (1994). The PATHS (Promoting alternative thinking strategies) curriculum. South Deerfield, MA: Channing-Bete Co.

Larun, L., Nordheim, L. V., Ekeland, E., Hagen, K. B., & Heian, F. (2006). Exercise in prevention and treatment of anxiety and depression among children and young people. *Cochrane Database of Systematic Reviews, 3*. doi:10.1002/14651858.CD004691.pub2

Lehr, D., Hillert, A., Schmitz, E., & Sosnowsky, N. (2008). Screening depressiver Störungen mittels Allgemeiner Depressions-Skala (ADS-K) und State-Trait Depressions Scales (STDS-T): Eine vergleichende Evaluation von Cut-Off-Werten [Assessing depressive disorders using the Center for Epidemiologic Studies-Depression Scale (CES-D) and State-Trait Depression Scales (STDS-T): A comparative analysis of cut-off scores]. *Diagnostica, 54*, 61–70. doi:10.1026/0012-1924.54.2.61

Medina, J. A., Netto, L. B., Muszkat, M., Medina, A. C., Botter, D., Orbetelli, R., … Miranda, M. C. (2010). Exercise impact on sustained attention of ADHD children, methylphenidate effects. *ADHD, 2*, 49–58. doi:10.1007/s12402-009-0018-y

Melchers, P., & Preuss, U. (2001). *Kaufman-Assessment Battery for Children* [German version]. Leiden, Germany: PITS.

Meyer, T. D., & Hautzinger, M. (2001). Allgemeine Depressions-Skala (ADS): Normierung an Minderjährigen und Erweiterung zur Erfassung manischer Symptome (ADMS) [Center for Epidemiologic Studies - Depression Scale (CES-D): Norms for adolescents and extension for the assessment of manic symptoms]. *Diagnostica, 47*, 208–215. doi:10.1026//0012-1924.47.4.208

Mitre, N., Lanningham-Foster, L., Foster, R., & Levine, J. A. (2009). Pedometer accuracy for children: Can we recommend them for our obese population? *Pediatrics, 123*, 127–131. doi:10.1542/peds.2008-1908

Moore, R. D., Wu, C. T., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Raine, L. B., Johnson, C. R., & Hillman, C. H. (2013). Aerobic fitness and intra-individual variability of neurocognition in preadolescent children. *Brain and Cognition, 82*, 43–57.

Moosbrugger, H., & Goldhammer, F. (2007). *FAKT-II. Frankfurter Adaptiver Konzentrationsleistungs-Test II.* [FAKT-II. Frankfurt Adaptive Attention-Test]. Bern, Swiss: Huber.

Murray-Close, D., Hoza, B., Hinshaw, S. P., Arnold, L. E., Swanson, J., Jensen, P. S., … Wells, K. (2011). Developmental processes in peer problems of children with ADHD in the MTA Study: Developmental cascades and vicious cycles. *Development and Psychopathology, 22*, 785–802. doi:10.1017/S0954579410000465

Nader, P. R., Bradley, R. H., Houts, R. M., McRitchie, S. L., & O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *Journal of the American Medical Association, 300*, 295–305. doi:10.1001/jama.300.3.295

Nakae, S., Oshima, Y., & Ishii, K. (2008). Accuracy of spring-levered and piezo-electric pedometers in primary school Japanese children. *Journal of Physiological Anthropology, 27*, 233–239. doi:10.2114/jpa2.27.233

Pagoto, S., Curtin, C., Appelhans, B. M., & Alonso-Alonso, M. (2012). Attention deficit/hyperactivity disorder and the clinical management of obesity. *Current Obesity Reports, 1*, 80–86. doi:10.1007/s13679-012-0012-0

Petermann, F., & Petermann, U. (2007). *Hamburg-Wechsler-Intelligenztest für Kinder IV (HAWIK-IV)* [German version of the Wechsler Intelligence Scale for Children (WISC-IV)]. Bern, Swiss: Huber.

Redick, T. S., Broadway, J. M., Meier, M. E., Kuriakose, P. S., Unsworth, N., Kane, M. J., & Engle, R. W. (2012). Measuring working memory capacity with automated complex span tasks. *European Journal of Psychological Assessment, 28*, 164171. doi:10.1027/1015-5759/a000123

Reed, J., & Ones, D. S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport and Exercise, 7*, 477–514. doi:10.1016/j.psychsport.2005.11.003

Salvy, S. J., Bowker, J. W., Roemmich, J. N., Romero, N., Kieffer, E., Paluch, R., & Epstein, L. H. (2008). Peer influence on children's physical activity: An experience sampling study. *Journal of Pediatric Psychology, 33*, 39–49. doi:10.1093/jpepsy/jsm039

Shipstead, Z., Redick, T. S., & Engle, R. W. (2012). Is working memory training effective? *Psychological Bulletin, 138*, 628-654. doi:10.1037/a0027473

Teychenne, M., Ball, K., & Salmon, J. (2008). Physical activity and likelihood of depression in adults: A review. *Preventive Medicine, 46*, 397–411. doi:10.1016/j.ypmed.2008.01.009

Thorell, L. B., Linqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*, 106–113.doi:10.1111/j.1467-7687.2008.00745.x

Tudor-Locke, C., McClain, J. J., Hart, T. L., Sisson, S. B., & Washington, T. L. (2009). Pedometry methods for assessing free-living youth. *Research Quarterly for Exercise and Sport, 80*, 175–184.

Verret, C., Guay, M.-C., Berthiaume, C., Gardiner, P., & Béliveau, L. (2012). A physical activity program improves behavior and cognitive functions in children with ADHD: An exploratory study. *Journal of Attention Disorders, 16*, 71–80. doi:0.1177/1087054710379735

Wahlstedt, C., Thorell, L. B., &Bohlin, G. (2009). Heterogeneity in ADHD: neuropsychological pathways, comorbidity and symptom domains. *Journal of Abnormal Child Psychology, 37,* 551-564. doi: 10.1007/s10802-008-9286-9.

Woerner, W., Fleitlich-Bilyk, B., Martinussen, R., Fletcher, J., Cucchiaro, G., Dalgalarrondo, P., …Tannock, R. (2004). The Strengths and Difficulties Questionnaire overseas: Evaluations and applications of the SDQ beyond Europe. *European Child and Adolescent Psychiatry, 13*(Suppl. 2), 47–54. doi:10.1007/s00787-004-2008-0

World Health Organization (1991). *Internationale Klassifikation psychischer Störungen: ICD 10, Kapitel V.* [Tenth Revision of the International Classification of Diseases, Chapter V (F): Mental and Behavioral Disorders]. Bern, Swiss: Huber.

World Health Organization. (2007). *BMI-for-age (5-19 years)*. Retrieved from http://www.who.int/growthref/who2007_bmi_for_age/en/index.html.

Zimmermann, P., & Fimm, B. (2006). *Testbatterie zur Aufmerksamkeitsprüfung (TAP)* [Test of Attentional Performance (TAP)]. Herzogenrath, Germany: Psytest.

Table 1

Sample Characteristics in Study 1 (N = 38 adolescents)

Variables	
Mean age in years (*SD*)	14.37 (1.88)
Gender	
Boys, %	47.4
Family income (SES)	
Below €1,500, %	12.9
Between €1,500 and €4,000, %	54.9
Above €4,500, %	32.2
Highest education level (SES)	
≤ 10 years of school (mothers), %	54.5
≤ 10 years of school (fathers), %	48.4
Weight	
Mean Body Mass Index (*SD*)	19.23 (1.89)
Overweight,[a] %	7.9
Mean step counts (*SD*)	8,486[b] (4,941)
Mean hyperactivity (*SD*)	0.63 (0.59)
Depressive symptoms (CES-D)	
Mean Composite Score (*SD*)	9.84 (7.79)
Depressed,[c] %	15.6

Note: CES-D = Center for Epidemiologic Studies - Depression Scale, German 15-item short version; SES = socioeconomic status (valid data for 31 parents).
[a]Overweight according to World Health Organization BMI standards for children (2007).
[b]The mean daily step count for an average child in this study would translate into energy expenditure of 64.94 kcal per kg per week (using the equation suggested by Mitre, Lanningham-Foster, Foster, & Levine, 2009).
[c]Categorized as depressed, if 15-item CES-D composite score ≥ 18 (see Lehr, Hillert, Schmitz, & Sosnowsky, 2008).

Table 2

Hyperactivity and Physical Activity as Predictors of Depressed Affect, Fixed and Random Effects (Study 1)

		Depressed Affect	
Fixed Effect		Estimate[a]	SE
Intercept	γ_{00}	1.44*	0.09
Time (Diary Day centered at Day 5)	$\gamma_{10}Dayc5_{it}$	-0.03	0.02
Hyperactivity	$\gamma_{01}Hyperc_{i}$	0.10	0.14
Physical Activity, Within-Person	$\gamma_{11}StepsW_{it}$	-0.29*	0.11
Physical Activity, Within-Person x Hyperactivity	$\gamma_{12}StepsW_{it}$ x $Hyperc_{i}$	-0.38*	0.17
Physical Activity, Between-Person	$\gamma_{02}StepsBc_{i}$	0.03	0.26
Physical Activity, Between-Person x Hyperactivity	$\gamma_{03}StepsBc_{i}$ x $Hyperc_{i}$	-0.58	0.39
Random Effects (Variances)			
Level 2 (between-person)			
Intercept	u_{0i}	0.21*	0.07
Time	u_{1i}	0.00	0.00
Level 1 (within-person)			
Residual	ε_{it}	0.32*	0.04

Note. Estimates for fixed effects are unstandardized regression coefficients.

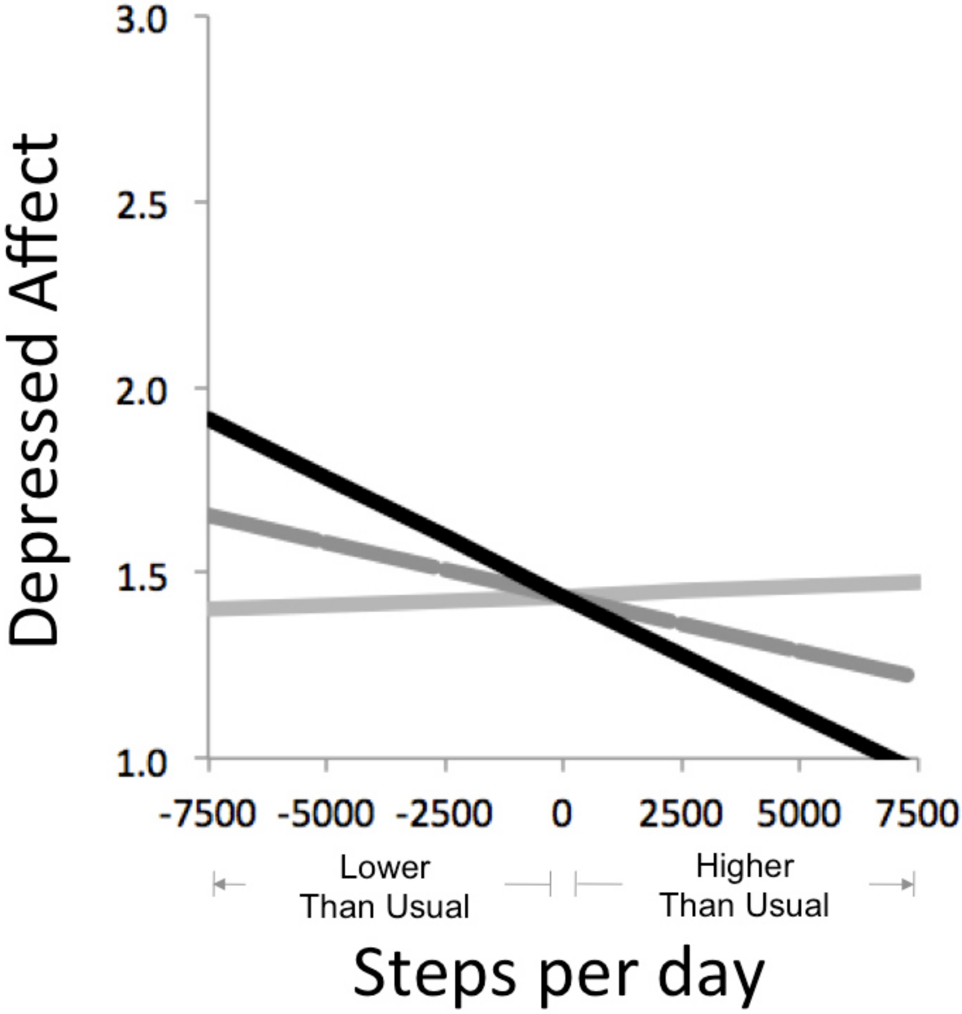

Figure 1. Hyperactivity as a moderator of the within-person association of physical activity and depressed affect (Study 1). On days when participants were more physically active than usual, depressed affect was lower, and this effect was more pronounced in participants with higher levels of hyperactivity (black line: participants with high hyperactivity, medium grey line: average hyperactivity, light grey line: low hyperactivity).

5.3 Appendix C: Manuscript III

Within-Person Link between Depressed Affect and Moderate-to-Vigorous Physical Activity in Adolescence: An Intensive Longitudinal Approach

Nadine Langguth[a,b], Johanna Schmid[a,b,c], Caterina Gawrilow[a,b,c], and Gertraud Stadler[d,e]

[a]German Institute for International Educational Research (DIPF), Frankfurt, Germany

[b]Center for Research on Individual Developmental and Adaptive Education of Children at Risk (IDeA-Center), Frankfurt, Germany

[c]LEAD Graduate School, Eberhard Karls Universität Tübingen, Germany

[d]Department of Applied Health Sciences, University of Aberdeen, Scotland

[e]Department of Psychology, Columbia University, New York, USA

Author Note

Nadine Langguth is now at the University Medical Center Hamburg-Eppendorf, Germany. Johanna Schmid and Caterina Gawrilow are now at the Eberhard Karls Universität Tübingen, Germany. Gertraud Stadler is now at the University of Aberdeen, Scotland.

We thank Danijela Bacic, Hannah Jöckel, Lea Köhler, Katrin Molsen, Marie Landenberger, and Annika Plambeck for their assistance with participant recruitment and data collection, Dale Esliger and Lauren Sherar for processing the accelerometry data, and Matthew Riccio for his helpful comments on the manuscript.

Correspondence concerning this article should be addressed to Nadine Langguth, University Medical Center Hamburg-Eppendorf, Department of Child and Adolescent Psychiatry and Psychotherapy, Martinistr. 52, 20246 Hamburg, Germany, phone: +49 (0) 40 7410-58475, fax: +49 (0) 40 7410-52409, e-mail: n.langguth@uke.de

Within-Person Link between Depressed Affect and Moderate-to-Vigorous Physical Activity in Adolescence: An Intensive Longitudinal Approach

Abstract

Background: During adolescence, young women and men frequently show low physical activity and elevated depressed affect. This study aimed to examine the within-person link between moderate-to-vigorous physical activity (MVPA) and depressed affect in everyday life. **Methods:** Within an intensive longitudinal approach, adolescents (*N* = 72; 37% young women; *M* age = 17.36 years; age range: 12-26 years; mid-90% age range: 13-22 years) wore accelerometers to assess their daily MVPA and reported next-morning and same-evening depressed affect in diaries over eight consecutive days. The within-person link between MVPA and depressed affect on the next morning (time-lagged prediction) and the same evening (same-day link) was analyzed with mixed-effects models. **Results:** More-than-usual MVPA significantly predicted less next-morning depressed affect on weekdays in young women, to the extent that a 60-min increase in MVPA over the person mean significantly predicted 50% lower next-morning depressed affect. **Conclusions:** This study encourages the development of individually-tailored physical activity interventions that could help adolescents enhance their daily amount of unstructured, self-initiated MVPA to reduce depressed affect. This approach may be particularly suitable for young women who have the highest risk for an inactive lifestyle and elevated depressed affect.

Keywords: moderate-to-vigorous physical activity, accelerometry, depressed affect, adolescence, within-person link, intensive longitudinal design

Introduction

Adolescence[1] is a high-risk period for elevated depressed affect (Thapar, Collishaw, Pine, & Thapar, 2012) and developing an inactive lifestyle (Kann et al., 2014). During this period depressed affect[2] becomes increasingly prevalent (Bertha & Balázs, 2013; Thapar et al., 2012), particularly in young women (Thapar et al., 2012; Wesselhoeft, Sørensen, Heiervang, & Bilenberg, 2013), and can be associated with severe social problems (Verboom, Sijtsema, Verhulst, Penninx, & Ormel, 2014), educational impairments (Verboom et al., 2014), and morbidity (Thapar et al., 2012).

During the same developmental period, everyday moderate-to-vigorous physical activity (MVPA) decreases by approximately 40 min per day each year (e.g., Nader, Bradley, McRitchie, Houts, & O'Brien, 2008). On weekend days, young women and men spend less time with MVPA compared to weekdays possibly due to competing weekend priorities and fewer opportunities for participation in MVPA (Comte et al., 2013; Corder et al., 2014; Nader et al., 2008; Ortega et al., 2013). Notably, MVPA decreases even sharper and more rapidly in young women than men (Hallal et al., 2012; Nader et al., 2008). Overall, the decline of MVPA during adolescence leads to various short- and long-term consequences for physical and mental health such as poorer cardiometabolic parameters (Ekelund et al., 2012) and higher levels of anxious and depressed affect (e.g., Janssen & LeBlanc, 2010).

---

[1] In this article we follow the suggestion of Sawyers and colleagues (2012) who defined "adolescence" as the period between ages 10 and 24; thus, we use the terms adolescents and young women and men to refer to this age group.

[2] When using the term depressed affect researchers generally refer to a core symptom of depression (i.e., being sad, discouraged, downhearted, or hopeless). Within intensive longitudinal studies, depressed affect is mostly conceptualized as transient episodes occurring frequently in everyday life that can be readily changed by social, psychological, and environmental contexts (Cranford et al., 2006).

Although there is ample evidence that enhanced physical activity is associated with lower depressed affect (Brown, Pearson, Braithwaite, Brown, & Biddle, 2013; Cooney, Dwan, & Mead, 2014; Larun, Nordheim, Ekeland, Hagen, & Heian, 2006; Mammen & Faulkner, 2013), the underlying mechanisms are still poorly understood (Josefsson, Lindwall, & Archer, 2014). Possible explanations for the antidepressant effect associated with activity include immediate-to-short-term and longer-term physiological mechanisms (e.g., increased synthesis of norepinephrine and serotonin, increased blood circulation, Buckworth, Dishman, O'Connor, & Tomporowski, 2013; increased synthesis of endorphins, dopamine, and endocannabinoids, Ekkekakis, 2013; neuroimmune modulation, i.e., reduced inflammation and oxidation stress, Eyre & Baune, 2012; enhanced energy and lower fatigue, Loy, O'Connor, & Dishman, 2013; circadian rhythm reset through natural light exposure, Stephenson, Schroder, Bertschy, & Bourgin, 2012) as well as psychological mechanisms (e.g., better sleep quality, Brand et al., 2014; van Zundert, van Roekel, Engels, & Scholte, 2015; distraction from worries, subjective expectations, physical activity enjoyment, social participation and support, Salmon, 2001; enhanced control beliefs, Buckworth et al., 2013; improved physical self-concept, self-efficacy, and self-esteem, Babic et al., 2014).

In sum, studying the link between everyday MVPA and depressed affect within person seems very promising to see if MVPA could be used as an intervention to prevent depressed affect.

Previous Studies on the Link between Physical Activity and Depressed Affect in Adolescence

To date, most studies involving young women and men have focused on linking differences in physical activity and depressed affect *between* individuals (between-person link). The majority of these studies followed cross-sectional designs and showed small to moderate negative associations between activity and depressed affect (e.g., Janssen &

LeBlanc, 2010). The few existing mid- and long-term longitudinal studies examining this association over months or years predominantly showed that higher activity levels are prospectively related to lower depressed affect (Mammen & Faulkner, 2013). Moreover, randomized controlled trials (RCTs) suggest that activity interventions reduce depressed affect in adolescents (Brown et al., 2013; Larun et al., 2006).

Despite the valuable contributions of cross-sectional and longitudinal studies, and RCTs to understanding the physical activity-depressed affect link in adolescence, these studies are not without limitations. First, particularly cross-sectional and longitudinal studies generally used self-reports assessing past activity instead of motion sensors (i.e., accelerometers or pedometers) measuring concurrent activity, potentially resulting in recall bias and overestimation of the actual amount of activity (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009). Second, especially in RCTs, activity is usually conceptualized as prescribed, structured, and supervised exercise under laboratory conditions and not as self-initiated, unsupervised everyday activity in real-world settings, thereby reducing the generalizability of results. Third, by focusing almost entirely on between-person effects, previous studies are mostly unable to capture fluctuations over time *within* individuals (within-person link; Kanning, Ebner-Priemer, & Schlicht, 2013). Since results at the between-person level do not necessarily translate to those at the within-person level (Hamaker, 2012) the question of whether more activity is related to lower depressed affect *within* young women and men remains largely unanswered (Biddle & Asare, 2011; Hume et al., 2011).

Intensive Longitudinal Studies on the Within-Person Link between Physical Activity and Affect in Adolescence

To examine psychological processes occurring at the within-person level from day to day and within the same day, intensive longitudinal designs are considered the method of choice (Bolger & Laurenceau, 2013). These designs include sequences of repeated measurements taken on individuals in everyday contexts to examine change processes within individuals. Studies with intensive longitudinal designs have two key advantages over studies with cross-sectional, mid- and long-term longitudinal, as well as intervention designs. First, researchers can systematically examine naturally occurring processes on a day-to-day basis in real-world settings, thereby enhancing the ecological validity and reducing recall bias (Reis, 2012). Second, the focus on within-person processes has the advantage that only a few time-varying constructs with similar timing could be alternative explanations. Thus, researchers can rule out explanations through stable between-person differences such as socioeconomic status. Intensive longitudinal studies enable researchers to study if more MVPA indeed precedes less depressed affect within the same person, thus providing the basis for claiming a temporal order—a precondition for causality which, then, has to be tested within experiments.

So far, there are very few intensive longitudinal studies of the physical activity-affect link. In adults, two intensive longitudinal studies (Mata et al., 2012; Wichers et al., 2012) showed within-person links between activity and positive affect, but not negative affect, possibly due to the measurement approach for activity (self-report) and for negative affect (heterogeneous items with low sensitivity to change and partially low within-person reliability). Hence, these studies cannot convincingly rule out a within-person link between activity and negative affect in adults due to methodological restrictions. With regard to childhood and adolescence, there are three intensive longitudinal studies, all of them using sensor-based assessment of activity (Dunton et al., 2014; Gawrilow, Stadler, Langguth, Naumann, & Boeck, 2013; Kühnhausen, Leonhardt, Dirk, & Schmiedek, 2013). Neither Dunton and colleagues (2014) nor Kühnhausen and colleagues (2013) could show a within-person link between activity and negative affect in elementary school children, possibly due methodological restrictions such as participants' young age, item selection, scale reliability, and for Kühnhausen and colleagues low mean levels and variability of affect. Gawrilow and colleagues (2013) showed that boys and girls in early adolescence reported less evening depressed affect on days when they had taken more-than-usual steps. In sum, the activity-affect link has been investigated with mixed results, and only a handful of studies focused on adolescence and early adulthood.

Research Questions and Hypotheses

We addressed the following two research questions: Does accelerometer-assessed MVPA on one day predict (a) next-morning and (b) same-evening depressed affect[3] within person? We hypothesized that young women and men with more-than-usual physical activity throughout the day (i.e., over the person mean) would show (a) less depressed affect on the next morning (time-lagged prediction) and (b) the same evening (same-day link). We focused on MVPA because this intensity level showed the strongest impact on depressed affect in previous research (Brunet et al., 2013). Since activity and depressed affect differ considerably between young women and men (i.e., more activity in young men, higher depressed affect in young women) and weekdays and weekend days (i.e., more activity and higher depressed affect on weekdays; Cranford et al., 2006; Hallal et al., 2012; Nader et al., 2008), we examined gender and weekday vs. weekend day as moderators of within-person links.

Methods

Design and Procedure

This study had an intensive longitudinal design with a baseline questionnaire, seven consecutive days of daily physical activity and depressed affect assessment (i.e., five weekdays, two weekend days), and a follow-up questionnaire. Participants were recruited from two public secondary schools (Grades 7-12) and one vocational school (Grades 10-12)

---

[3] In the current study, we used three items of the Profile of Mood States (sad, discouraged, hopeless; Cranford et al., 2006; McNair, Lorr, & Droppleman, 1992) to define depressed affect.

in a large urban area in Germany. Trained research assistants explained the study procedure in the classroom, handed out a written study description, and assured them that their participation would be voluntary and that their answers would remain completely confidential. Participants and their parents (for those under 18) provided written informed consent.

Participants completed the baseline questionnaire on single desks in the school hall. Subsequently, in pairs of two students, participants were shown how to wear the accelerometer and received paper-and-pencil morning and, if requested, paper-and-pencil evening diaries for all days. Those participants who had chosen the online format for filling out evening diaries were instructed that they would receive a link to each evening diary at 7 pm every day via e-mail. For the following seven consecutive days, participants wore an accelerometer on their right waistband during waking hours on all days except during water-based activities (Day 1 to 7). On Day 2 to 8, participants reported their morning depressed affect within one hour of waking up via paper-and-pencil diaries (using this format allowed all participants to integrate their ratings into their daily morning routine). On Day 1 to 7, participants reported their evening depressed affect within one hour of going to sleep depending on participants' preference via paper-and-pencil diaries (78% of participants) or online diaries (22%). On Day 8, participants completed a follow-up questionnaire, and research assistants collected accelerometers and paper-and-pencil diaries. All data were collected between September and December 2011. The research protocol was approved by the local Institutional Review Board.

Measures

Daily physical activity. We measured daily physical activity using GT3X+ accelerometers by ActiGraph (Pensacola, FL, US). The sampling rate was set to 60 Hz and the non-wear time was determined as 60 min of consecutive zeros of activity counts allowing for two min of non-zero interruptions. Days with wear times of 10 or more hours were considered as valid days (Colley, Connor Gorber, & Tremblay, 2010). All participants with at least one valid day of activity (and affect) assessment were included in the analyses (see Appendix B for sample composition).[4] Data were downloaded and aggregated into 15-s epochs by using ActiLife 5. After scanning for spurious data, epochs were aggregated to MVPA min per day using KineSoft version 3.3.67 (KineSoft, Saskatchewan, Canada; http://www.kinesoft.org). We used well-established MVPA cut points (≥ 2020 counts per min, cpm; Troiano et al., 2008)[5]. Detailed information on valid days, wear time, and MVPA min are given in Table 1.

Morning and evening depressed affect. Depressed affect was assessed in morning and evening diaries with three items (sad, discouraged, hopeless) from the POMS (Profile of Mood States; Cranford et al., 2006; McNair, Lorr, & Droppleman, 1992). These items were particularly designed for use in intensive longitudinal studies and are a reliable measure of within-person change (Cranford et al., 2006); they were previously pilot tested for adolescents (Gawrilow et al., 2013) as recommended by Shrout and Lane (2012). In the morning and evening, participants rated their *current* depressed affect ("How do you feel *right now*?") using a 5-point scale ranging from 0 (*not at all*) to 4 (*extremely*). For each individual we computed a mean score for each morning and evening (Table 1). The within-person reliability (Shrout & Lane, 2012) for morning and evening depressed affect was good ($\alpha = .80$ and $\alpha = .79$, respectively).

Retrospective report on depressed affect. To describe the sample, we assessed depressed affect retrospectively with the German 20-item Center for Epidemiologic Studies –

[4] Participants with only one day of physical activity assessment do not contribute to estimating the within-person effect but to estimating the other effects in the model.

[5] Cut-points for all physical activity intensity levels published by Troiano and colleagues (2008): sedentary (< 100 cpm), light (≥ 100 < 2020 cpm), moderate (≥ 2020 < 6000 cpm), and vigorous activity (≥ 6000 cpm).

Depression Scale (CES-D; Hautzinger, Bailer, Hofmeister, & Keller, 2012). Items were rated with regard to the past week using a 4-point scale ranging from 0 (*rarely or none of the time*) to 3 (*most or all of the time*). The CES-D composite score can vary between 0 and 60, with values ≥ 23 indicating elevated depressed affect (Hautzinger et al., 2012). The internal consistency of the scale was good (Cronbach's α = .83).

Socio-demographic characteristics. We asked participants to indicate their age, gender, grade, country of origin, and intended highest education level as well as their parents' country of origin and education level (Table 1).

Analyses

All analyses were conducted with IBM SPSS Statistics 21. Concerning MVPA only Day 1 to 7 (i.e., days with full-day physical activity assessment) were selected for analyses; participants' morning (Day 2 to 8) and evening depressed affect (Day 1-7) were also incorporated. We analyzed the within-person link between MVPA and next-morning depressed affect (time-lagged prediction) and same-evening depressed affect (same-day link) using mixed-effects models (Bolger & Laurenceau, 2013). Gender and weekend were included as moderators in the model. By centering all time varying variables within-person we ruled out that the current findings can be explained by between-person differences in these variables. For all analyses, a probability level of $p < .05$ indicated significance. For more details on the analyses of the time-lagged prediction and the same-day link including an exemplary equation see supporting online information (Appendix A).

Results

Descriptives and Sample Characteristics

Eighty-seven out of 124 participants wore the accelerometer for at least 10 hours on at least one day, with an average of six accelerometer days available per participant. Of these, 72 adolescents (37% young women; *M* age = 17.36 years; age range: 12-26 years; mid-90%

age range: 13-22 years) also provided daily ratings of depressed affect at least once and completed nearly all morning and evening diaries (6.75 and 6.13, respectively, out of 7.00 possible entries). In total, we analyzed 362 valid days for the time-lagged prediction and 346 valid days for the same-day link, where valid daily assessments of both physical activity and depressed affect were available. For more details on sample size and sample composition, and dropout analysis see Appendices B and C.

Participants provided valid data for MVPA on 5.38 days (out of 7.00 possible days) with an average daily wear time of approximately 16.00 hours, with young women providing more valid days and longer wear time on weekdays and weekend days than young men. On weekdays, young women were engaged in MVPA for approximately 1.00 hour per day; young men were active for approximately 1.00 hour and 20 min per day. Similar to weekdays, on weekend days, the average amount of MVPA varied equally between young women (0.75 hours per day) and men (1.00 hours per day). On weekdays and weekend days, young women and men did not differ in their person mean of next-morning and same-evening depressed affect (see Table 1). On weekdays and weekend days, young women and men did not significantly differ in their day-to-day variability of next-morning and same-evening depressed affect.

Over 90% of participants were aiming for a university-entrance exam. Most of them (87%) were born in Germany and 41% had at least one parent with another country of origin. Two thirds of participants had at least one parent who had passed the university-entrance exam and 41% of parents obtained a university degree. Further details on descriptives including a comparison of sample characteristics between young women and men (a probability level of $p < .05$ indicates significance) are displayed in Table 1 (see Appendix D for between-person correlations of descriptives and sample characteristics).

Does Moderate-to-Vigorous Physical Activity Predict Less Next-Morning Depressed Affect?

With dummy-coded gender (0 = women, 1 = men) and day of the week (0 = weekday, 1 = weekend day), the intercept indicates the average next-morning depressed affect for young women on weekdays ($\gamma_0 = 0.46$, $p < .001$); young men did not differ from young women in average next-morning depressed affect ($\gamma_1 = 0.02$, *ns*). Young women did not differ in next-morning depressed affect between weekdays and weekend days ($\gamma_2 = -0.07$, *ns*), and young men's weekdays-weekend days difference in depressed affect was not significantly weaker or stronger than women's difference ($\gamma_3 = -0.07$, *ns*). Next, we found the following four activity-affect links: For young women on weekdays, a 60-min increase in MVPA over the person mean predicted 50% lower next-morning depressed affect ($\gamma_4 = -0.24$, $p = .03$). Young men's activity-affect link on weekdays differed from young women's ($\gamma_5 = 0.26$, $p = .05$); simple slope analysis showed that on weekdays in men, a 60-min increase in MVPA over the person mean did not predict lower next-morning depressed affect (-0.24 + 0.26 = 0.02). Young women differed in their activity-affect link between weekdays and weekend days ($\gamma_6 = 0.37$, $p = .03$); simple slope analysis showed that for young women on weekend days higher MVPA did not predict lower next-morning depressed affect (-0.24 + 0.37 = 0.13). Young men's difference in the activity-affect link between weekdays and weekend days did not differ from young women's difference ($\gamma_7 = -0.26$, *ns*); simple slope analysis showed that for young men on weekend days higher MVPA did not predict lower next morning depressed affect (-0.24 + 0.26 + 0.37 – 0.26 = 0.13). In sum, there was a lagged-time prediction of next-morning depressed affect by MVPA on weekdays for young women but not young men (see Figure 1; see Appendix E for effects in within-person correlations). We tested the effects of potential confounding variables (studyday, wear time) on next-morning depressed affect. Because studyday and wear time did not change the pattern of results in sensitivity analyses, we report the more parsimonious model.

[Table 2 here]

Does Moderate-to-Vigorous Physical Activity Predict Less Same-Evening Depressed Affect?

There was no same-day link between MVPA and evening depressed affect on weekdays or weekend days neither in young women nor men (see Figure 1; see Appendix E for effects in within-person correlation metric). For details on findings of the same-day link see Appendix F. Studyday and wear time did not change the pattern of results in sensitivity analyses; thus, we report the more parsimonious model.

[Figure 1 here]

Discussion

In the present intensive longitudinal study, we examined the within-person links between accelerometer-based daily MVPA and next-morning and same-evening depressed affect in young women and men. More-than-usual MVPA predicted significantly less next-morning depressed affect on weekdays in young women but not in men. In young women in our sample on weekdays, a 60-min increase in MVPA over the person mean significantly predicted 50% lower next-morning depressed affect. In young men on weekdays, more-than-usual MVPA did not predict less next-morning depressed affect. On weekend days, neither young women nor men showed an activity-affect link. More-than-usual MVPA did not predict less same-evening depressed affect, regardless of gender or weekday vs. weekend day. To our knowledge, there are no comparable studies that have investigated this time-lagged prediction in this age group.

There are several possible explanations for the weekday vs. weekend day effect found (i.e., time-lagged prediction on weekdays but not weekend days). First, one reason could be the higher amount of MVPA on weekdays compared to weekend days in our study. This higher amount on weekdays is possibly due to more opportunities for structured physical activity (e.g., in sports clubs and physical education classes) on weekdays than on the weekend (Comte et al., 2013; Ortega et al., 2013)[6]. Second, because we included five weekdays but only two weekend days for analyses in this study, the weekday effect of activity on depressed affect was estimated with higher precision than the weekend effect, and studies with longer duration are needed to deliver a more definitive answer regarding this weekday–weekend discrepancy.

Explanations for the gender effect found (i.e., time-lagged prediction for young women but not men) could be due to (a) differences in assessment of depressed affect and physical activity, (b) developmental differences in self-esteem, physical self-concept, and motivation, and (c) dose-response differences. First, regarding depressed affect, we found no significant differences in mean depressed affect or variability of depressed affect between young women and men that could explain this finding. Instead, differences in activity may be a more likely explanation: As we measured activity with accelerometers but not with additional questionnaires, we could not study the influence of activity type (individual vs. team sports; cooperative vs. competitive) or environment (outdoor vs. indoor). These context factors, however, are associated with activity enjoyment (Burton, Khan, & Brown, 2012) and might influence depressed affect. For example, we could not investigate whether young men were predominantly engaged in competitive activities ("win-or-lose", "fight-or-flight") whereas young women were mostly engaged in cooperative activities (supportive, "tend-and-befriend"; Asztalos et al., 2012) with potentially different effects on depressed affect. Through cooperative activities young women could attempt to satisfy their need for affiliation (due to pubertal changes in hormone regulation; Patton & Viner, 2007), leading to

---

[6] Higher activity on weekdays compared to the weekend days was not an artifact of higher accelerometer wear time on weekdays vs. weekend days, as we found uniformly high wear time of 16 hours per day.

reduced depressed affect. As shown by Lewis and colleagues (2015), young women who lack this emotional connectedness tend to report more depressed affect than young women who have more satisfactory relationships. Second, during puberty, physical changes vary considerably by gender (tripled vs. double total body fat mass in young women vs. men; Siervogel et al., 2003) and may contribute to gender differences in the activity-depressed affect link. Thus, particularly in young women, differences between internalized ideal body shape and real body shape may lead to increased body dissatisfaction (e.g., Tiggemann, 2011). Improving self-esteem and physical self-concept through more activity (Babic et al., 2014; Dishman et al., 2006) may lead to increased body satisfaction particularly in young women (Greenleaf, Boyer, & Petrie, 2009) and, thus, to lower depressed affect. Taken together, more negative psychological reactions to bodily changes of young women compared to men during adolescence may explain the positive impact of activity on depressed affect in young women (Patton & Viner, 2007). Third, motives for activity (e.g., appearance, competition, or companionship; Ingledew, Markland, & Strömmer, 2014) or motivational regulation (e.g., external or internal motivation; Deci & Ryan, 2002) could also have differed between young women and men and might have contributed to the gender effect found. Fourth, it could be possible that young women require lower doses of activity than men to experience benefits for affect; thus, these thresholds should be examined in future studies (Dunn, Trivedi, & O'Neal, 2001).

Explanations for the missing same-day link could be due to (a) temporal dynamics between physical activity and depressed affect and (b) the impact of sleep duration and quality on the activity-depressed affect link. First, because depressed affect reported the same evening was comparable to reports the next morning in level and variability, again, depressed affect is an unlikely explanation of this finding. Instead, this finding raises the interesting question about temporal dynamics in the activity-depressed affect link. On the same day, do the immediate effects of MVPA on depressed affect occur within a short time window (e.g., within the next three hours after activity; see Wichers et al., 2012) and vanish across the day due to other emotional experiences (Wrzus, Müller, Wagner, Lindenberger, & Riediger, 2013) or increasing fatigue (Kim, Kikuchi, & Yamamoto, 2013)? Second, the effect of activity on next-morning depressed affect could emerge due to better sleep after an active day. Few intensive longitudinal studies have investigated the association between activity and sleep during adolescence. A cross-sectional study showed (Brand et al., 2014) that more activity throughout the day was associated with better sleep during the following night in this age group. Prior research on the effect of sleep on negative affect showed that adolescents who sleep less the previous night reported more negative affect the next day (Wrzus, Wagner, & Riediger, 2014). Moreover, poorer sleep quality during the night has been shown to predict more negative affect the next day—and this association was strongest in young women (van Zundert et al., 2015).

Limitations and Strengths

The study has several limitations. First, since we measured depressed affect only twice per day, we cannot draw conclusions about causality. However, the significant time-lagged prediction shown in this study is a valuable starting point for investigating the cause-and-effect relationships linking physical activity and depressed affect within person. Future intensive longitudinal designs with higher sampling frequency may resolve this question. Second, we cannot answer the question which mediating mechanisms might have encouraged the decrease of next-morning depressed affect on weekdays in young women. Including promising process variables such as sleep quality would be an important contribution in future studies. In this regard, studying the impact of activity on other depressive symptoms (e.g., lack of energy or fatigue) could also be worthwhile, since activity has been shown to improve other depressive symptoms in young women than men (McKercher et al., 2013).

Third, at the time of the study a considerable subgroup of participants did not have reliable access to a home computer or smartphone and chose, therefore, to fill out paper-and-pencil evening diaries instead of online diaries to assess depressed affect, thus time stamps were only available for online evening diaries. However, participants showed high study commitment and wore their accelerometer assiduously. When attaching and removing the accelerometer, we assume participants were reminded to complete their morning and evening diaries. Thus, we assume that compliance didn't differ between the two modalities. Fourth, the current study design included only one weekend. To gain more power while studying the weekday vs. weekend effect on the within-person link, activity and depressed affect should be measured on more than one weekend.

Despite these limitations, the present study makes several important contributions. First, this is the first study that investigates the within-person link between physical activity and next-morning and same-evening depressed affect in young women and men. By capturing the within-person variability in adolescents' activity and depressed affect, this study contributes to the limited body of literature and improves our understanding of the day-to-day association between activity and depressed affect in this age group. Second, we measured depressed affect using three items previously proved to be reliable and valid to assess within-person change (Cranford et al., 2006); we also showed adequate reliability of these items for measuring within-person change within this sample of adolescents. Third, we measured young women's and men's activity by using accelerometers which are considered the gold standard in activity research because self-report questionnaires tend to overestimate the amount of activity (e.g., Corder, Ekelund, Steele, Wareham, & Brage, 2008). As recommended by Cain, Sallis, Conway, Van Dyck, and Calhoon (2013), we monitored activity for seven consecutive days including weekend days to obtain reliable estimates for young women's and men's habitual activity. Fourth, by measuring unstructured, self-initiated activity in everyday life, that is, activity as it naturally occurs, we enhanced the ecological validity of our results. Our findings, taken together, are an important step towards understanding the temporal paths between activity and depressed affect in adolescents' everyday life.

Implications and Directions for Future Research

Further studies are needed to better understand the physical activity-depressed affect link in young women and men. To address the dynamics between activity and depressed affect, future research could measure depressed affect multiple times per day. Additionally, future research should study neurobiological mechanisms (e.g., neurotransmitter and endorphins) as possible mediators (for a review, see Dishman, Heath, & Lee, 2013). Intervention studies that enhance adolescents' activity through self-regulation strategies (Hynynen et al., 2014; Stadler, Oettingen, & Gollwitzer, 2009) seem to have a great potential to decrease depressed affect on a day-to-day basis in this age group.

Conclusion

This study provides evidence that it is feasible to use an intensive longitudinal design for school-based research on physical activity and depressed affect in young women and men. Given that adolescents are at high risk for developing an inactive lifestyle, this study encourages the development of individually-tailored activity interventions using an intensive longitudinal approach that could help adolescents enhance their daily amount of unstructured, self-initiated activity and reduce depressed affect. This approach may be particularly suitable for young women who have the highest risk for an inactive lifestyle and elevated depressed affect.

References

Adamo K. B., Prince, S. A., Tricco, A. C., Connor-Gorber, S., & Tremblay, M. (2009). A comparison of indirect versus direct measures for assessing physical activity in the pediatric population: A systematic review. *International Journal of Pediatric Obesity, 4*, 2–27. doi:10.1080/17477160802315010

Asztalos, M., Wijndaele, K., De Bourdeaudhuij, I., Philippaerts, R., Matton, L., Duvigneaud, N., ... & Cardon, G. (2012). Sport participation and stress among women and men. *Psychology of Sport and Exercise, 13*, 466–483. doi:10.1016/j.psychsport.2012.01.003

Babic, M. J., Morgan, P. J., Plotnikoff, R. C., Lonsdale, C., White, R. L., & Lubans, D. R. (2014). Physical activity and physical self-concept in youth: Systematic review and meta-analysis. *Sports Medicine, 44*, 1589–1601. doi:10.1007/s40279-014-0229-z

Bertha, E. A., & Balázs, J. (2013). Subthreshold depression in adolescence: a systematic review. *European Child & Adolescent Psychiatry, 22*, 589–603. doi:10.1007/s00787-013-0411-0

Biddle, S. J. H., & Asare, M. (2011). Physical activity and mental health in children and adolescents: a review of reviews. *British Journal of Sports Medicine, 45*, 886–895. doi:10.1136/886 bjsports-2011-090185

Bolger, N., & Laurenceau, J.-P. (2013). *Intensive longitudinal methods: an introduction to diary and experience sampling research*. New York, NY: Guilford.

Brand, S., Gerber, M., Beck, J., Hatzinger, M., Pühse, U., & Holsboer-Trachsler, E. (2014). High exercise levels are related to favorable sleep patterns and psychological functioning in adolescents: a comparison of athletes and controls. *Journal of Adolescent Health, 46*, 133–141. doi:10.1016/j.jadohealth.2009.06.018

Brown, H. E., Pearson, N., Braithwaite, R. E., Brown, W. J., & Biddle, S. J. (2013). Physical activity interventions and depression in children and adolescents. *Sports Medicine, 43*, 195–206. doi:10.1007/s40279-012-0015-8

Brunet, J., Sabiston, C. M., Chaiton, M., Barnett, T. A., O'Loughlin, E., Low, N. C. P., & O'Loughlin, J. L. (2013). The association between past and current physical activity and depressive symptoms in young adults: a 10-year prospective study. *Annals of Epidemiology, 23*, 25–30. doi:10.1016/j.annepidem.2012.10.006

Buckworth, J., Dishman, R. K., O'Connor, P. J., & Tomporowski, P. (2013). *Exercise psychology*. Champaign, IL: Human Kinetics.

Burton, N. W., Khan, A., & Brown, W. J. (2012). How, where and with whom? Physical activity context preferences of three adult groups at risk of inactivity. *British Journal of Sports Medicine, 46*, 1125–1131. doi:10.1136/bjsports-2011-090554

Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoon, L. (2013). Using accelerometers in youth physical activity studies: a review of methods. *Journal of Physical Activity & Health, 10*, 437–450.

Colley, R., Connor Gorber, S., & Tremblay, M. S., (2010). Quality control and data reduction procedures for accelerometry-derived measures of physical activity. *Health Reports, 21*, 63–69.

Comte, M., Hobin, E., Majumdar, S. R., Plotnikoff, R. C., Ball, G. D. C., McGavock, J., & MIPASS and Healthy Hearts Investigators Teams (2013). Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Applied Physiology, Nutrition, and Metabolism, 38*, 115–119. doi:10.1139/apnm-2012-0100

Cooney, G., Dwan, K., & Mead, G. (2014). Exercise for Depression. *Journal of the American Medical Association, 311*, 2432–2433. doi:10.1001/jama.2014.4930

Corder, K., Ekelund, U., Steele, R. M., Wareham, N. J., & Brage, S. (2008). Assessment of physical activity in youth. *Journal of Applied Physiology, 105*, 977–987. doi:10.1152/japplphysiol.00094.2008

Corder, K., Sharp, S. J., Atkin, A. J., Griffin, S. J., Jones, A. P., Ekelund, U., & van Sluijs, E. M. (2014). Change in objectively measured physical activity during the transition to adolescence. *British Journal of Sports Medicine*. Advance online publication. doi:10.1136/bjsports-2013-093190

Cranford, J. A., Shrout, P. E., Iida, M., Rafaeli, E., Yip, T., & Bolger, N. (2006). A procedure for evaluating sensitivity to within-person change: Can affect measures in diary studies detect change reliably? *Personality and Social Psychology Bulletin, 32*, 917–929. doi:10.1177/0146167206287721

Deci, E. L., & Ryan, R. M. (2002). *Handbook of self-determination research*. Rochester, NY: University of Rochester Press.

Dishman, R. K., Hales, D. P., Pfeiffer, K. A., Felton, G. A., Saunders, R., Ward, D. S., ... & Pate, R. R. (2006). Physical self-concept and self-esteem mediate cross-sectional relations of physical activity and sport participation with depression symptoms among adolescent girls. *Health Psychology, 25*, 396–407. doi:10.1037/0278-6133.25.3.396

Dishman, R., Heath, G., & Lee, I.-M. (2013). *Physical activity epidemiology*. Champaign, IL: Human Kinetics.

Dunn, A. L., Trivedi, M. H., & O'Neal, H. A. (2001). Physical activity dose-response effects on outcomes of depression and anxiety. Medi*cine & Science in Sports & Exercise, 33*, 587–597. doi:10.1097/00005768-200106001-00027

Dunton, G. F., Huh, J., Leventhal, A. M., Riggs, N., Hedeker, D., Spruijt-Metz, D., & Pentz, M. A. (2014). Momentary assessment of affect, physical feeling states, and physical activity in children. *Health Psychology, 33*, 255–263. doi:10.1037/a0032640

Ekelund, U., Luan, J., Sherar, L. B., Esliger, D. W., Griew, P., Cooper, A., & the International Children's Accelerometry Database (ICAD) Collaborators (2012). Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *The Journal of the American Medical Association, 307*, 704–712. doi:10.1001/jama.2012.156

Ekkekakis, P. (Ed.) (2013). *Routledge handbook of physical activity and mental health*. Abington, Oxon: Routledge.

Eyre, H., & Baune, B. T. (2012). Neuroplastic changes in depression: a role for the immune system. *Psychoneuroendocrinology, 37*, 1397–1416. doi:10.1016/j.psyneuen.2012.03.019

Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2013). Physical activity, affect, and cognition in children with symptoms of ADHD. *Journal of Attention Disorders*. Advance online publication. doi:10.1177/1087054713493318

Greenleaf, C., Boyer, E. M., & Petrie, T. A. (2009). High school sport participation and subsequent psychological well-being and physical activity: The mediating influences of body image, physical competence, and instrumentality. *Sex Roles, 61*, 714–726. doi:10.1007/s11199-009-9671-z

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet, 380*, 247–257. doi:10.1016/S0140-6736(12)60646-1

Hamaker, E. L. (2012). Why researchers should think "within-person": A paradigmatic rationale. In M. R. Mehl & T. S. Connor (Eds.), *Handbook of research methods for studying daily life* (pp. 43–61). New York, NY: Guilford.

Hautzinger, M., Bailer, M., Hofmeister, D., & Keller, F. (2012). *Allgemeine Depressionsskala (ADS)* [Center for Epidemiologic Studies – Depression Scale (CES-D)]. Göttingen, Germany: Hogrefe.

Hume, C., Timperio, A., Veitch, J., Salmon, J., Crawford, D., & Ball, K. (2011). Physical activity, sedentary behavior, and depressive symptoms among adolescents. *Journal of Physical Activity and Health, 8*, 152–156.

Hynynen, S. T., van Stralen, M. M., Sniehotta, F. F., Hardeman, W., Araujo-Soares, V., Hardeman, W., ... & Hankonen, N. (in press). A systematic review of school-based interventions targeting physical activity and sedentary behaviour among older adolescents. *International Review of Sport and Exercise Psychology*.

Ingledew, D. K., Markland, D., & Strömmer, S. T. (2014). Elucidating the roles of motives and gains in exercise participation. *Sport, Exercise, and Performance Psychology, 3*, 116–131. doi:10.1037/spy0000004

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*:40. doi:10.1186/1479-5868-7-40

Josefsson, T., Lindwall, M., & Archer, T. (2014). Physical exercise intervention in depressive disorders: Meta-analysis and systematic review. *Scandinavian Journal of Medicine & Science in Sports, 24*, 259–272. doi:10.1111/sms.12050

Kann, L., Kinchen, S., Shanklin, S. L., Flint, K. H., Kawkins, J., Harris, W. A., ... & Zaza, S. (2014). Youth risk behavior surveillance—United States, 2013. *Morbidity and Mortality Weekly Report, 63*, 1–168.

Kanning, M. K., Ebner-Priemer, U. W., & Schlicht, W. M. (2013). How to investigate within-subject associations between physical activity and momentary affective states in everyday life: a position statement based on a literature overview. *Frontiers in Psychology, 4*, 187. doi:10.3389/fpsyg.2013.00187.

Kim, J., Kikuchi, H., & Yamamoto, Y. (2013). Systematic comparison between ecological momentary assessment and day reconstruction method for fatigue and mood states in healthy adults. *British Journal of Health Psychology, 18*, 155–167. doi:10.1111/bjhp.12000

Kühnhausen, J., Leonhardt, A., Dirk, J., & Schmiedek, F. (2013). Physical activity and affect in elementary school children's daily lives. *Frontiers in Psychology, 4*, 456. doi:10.3389/fpsyg.2013.00456

Larun L., Nordheim L. V., Ekeland, E., Hagen, K. B., & Heian, F. (2006). Exercise in prevention and treatment of anxiety and depression among children and young people. *Cochrane Database of Systematic Reviews*, *3*:CD004691. doi:10.1002/14651858.CD004691.pub2

Lewis, A. J., Kremer, P., Douglas, K., Toumborou, J. W., Hameed, M. A., Patton, G. C., & Williams, J. (2015). Gender differences in adolescent depression: Differential female susceptibility to stressors affecting family functioning. *Australian Journal of Psychology, 67*, 131–139. doi:10.1111/ajpy.12086

Loy, B. D., O'Connor, P. J., & Dishman, R. K. (2013). The effect of a single bout of exercise on energy and fatigue states: a systematic review and meta-analysis. *Fatigue: Biomedicine, Health & Behavior, 1*, 223–242. doi:10.1080/21641846.2013.843266

Mammen, G., & Faulkner, G. (2013). Physical activity and the prevention of depression: a systematic review of prospective studies. *American Journal of Preventive Medicine, 45*, 649–657. doi:10.1016/j.amepre.2013.08.001

Mata, J., Thompson, R. J., Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Gotlib, I. H. (2012). Walk on the bright side: physical activity and affect in major depressive disorder. *Journal of Abnormal Psychology, 121*, 297–308. doi:10.1037/a0023533

McKercher, C., Patton, G. C., Schmidt, M. D., Venn, A. J., Dwyer, T., & Sanderson, K. (2013). Physical activity and depression symptom profiles in young men and women with major depression. *Psychosomatic Medicine, 75*, 366–374. doi:10.1097/PSY.0b013e31828c4d53

McNair, D. M., Lorr, M., & Droppleman, L. F. (1992). *Manual for the Profile of Mood States*. San Diego, CA: Educational and Industrial Testing Service.

Nader, P. R., Bradley, R. H., McRitchie, S. L., Houts, R. M., & O'Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *Journal of the American Medical Association, 300*, 295–305. doi:10.1001/jama.300.3.295

Ortega, F. B., Konstabel, K., Pasquali, E., Ruiz, J. R., Hurtig-Wennlöf, A., Mäestu, J., … & Sjöström, M. (2013). Objectively measured physical activity and sedentary time during childhood, adolescence and young adulthood: a cohort study. *PLoS One, 8*(4): e60871. doi:10.1371/journal.pone.0060871

Patton, G. C., & Viner, R. (2007). Pubertal transition in health. *Lancet, 369*, 1130–1139. doi:10.1016/S0140-6736(07)60366-3

Reis, H. (2012). Why researchers should think "real-world": A conceptual rationale. In M. R. Mehl & T. S. Conner (Eds.), *Handbook of research methods for studying daily life* (pp. 3–21). New York, NY: Guilford.

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: a unifying theory. *Clinical Psychology Review, 21*, 33–61. doi:10.1016/S0272-7358(99)00032-X

Sawyer, S. M., Afifi, R. A., Bearinger, L. H., Blakemore, S.-J., Dick, B., Ezeh, A. C. et al. (2012). Adolescence: A foundation for future health. *Lancet, 379*, 1630–1640. doi:10.1016/S0140-6736(12)60072-5

Shrout, P. E., & Lane, S. P. (2012). Psychometrics. In M. R. Mehl & T. S. Connor (Eds.), *Handbook of research methods for studying daily life* (pp. 302–320). New York, NY: Guilford.

Siervogel, R. M., Demerath, E. W., Schubert, C., Remsberg, K. E., Chumlea, W. C., Sun, S., … & Towne, B. (2003). Puberty and body composition. *Hormone Research, 60*, 36–45. doi:10.1159/000071224

Stadler, G., Oettingen, G., & Gollwitzer, P. M. (2009). Physical activity in women: Effects of a self-regulation intervention. *American Journal of Preventive Medicine, 36*, 29–34. doi:10.1016/j.amepre.2008.09.021

Stephenson, K. M., Schroder, C. M., Bertschy, G., & Bourgin, P. (2012). Complex interaction of circadian and non-circadian effects of light on mood: shedding new light on an old story. *Sleep Medicine Reviews, 16*, 445–454. doi:10.1016/j.smrv.2011.09.002

Thapar, A., Collishaw, S., Pine, D. S., & Thapar, A. K. (2012). Depression in adolescence. *Lancet, 379*, 1056–1067. doi:10.1016/S0140-6736(11)60871-4

Tiggemann, M. (2011). Sociocultural perspectives on human appearance and body image. In T. F. Cash & L. Smolak (Eds.), *Body image: A handbook of science, practice, and prevention* (pp. 12–19). New York, NY: Guilford.

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise, 40*, 181–188. doi:10.1249/mss.0b013e31815a51b3 van Zundert, R. M., van Roekel, E., Engels, R. C., & Scholte, R. H. (2015). Reciprocal associations between adolescents' night-time sleep and daytime affect and the role of gender and depressive symptoms. *Journal of Youth and Adolescence, 44*, 556–569. doi:10.1007/s10964-013-0009-3

Verboom, C. E., Sijtsema, J. J., Verhulst, F. C., Penninx, B. W., & Ormel, J. (2014). Longitudinal associations between depressive problems, academic performance, and social functioning in adolescent boys and girls. *Developmental Psychology, 50*, 247–257. doi:10.1037/a0032547

Wesselhoeft, R., Sørensen, M. J., Heiervang, E. R., & Bilenberg, N. (2013). Subthreshold depression in children and adolescents – a systematic review. *Journal of Affective Disorders, 151*, 7–22. doi:10.1016/j.jad.2013.06.010

Wichers, M., Peeters, F., Rutten, B. P., Jacobs, N., Derom, C., Thiery, E., ... & van Os, J. (2012). A time-lagged momentary assessment study on daily life physical activity and affect. *Health Psychology, 31*, 135–144. doi:10.1037/a0025688

Wrzus, C., Müller, V., Wagner, G. G., Lindenberger, U., & Riediger, M. (2013). Affective and cardiovascular responding to unpleasant events from adolescence to old age: Complexity of events matters. *Developmental Psychology, 49*, 384–397. doi:10.1037/a0028325

Wrzus, C., Wagner, G. G., & Riediger, M. (2014). Feeling good when sleeping in? Day-to-day associations between sleep duration and affective well-being differ from youth to old age. *Emotion, 14*, 624–628. doi:10.1037/a003534

Table 1

Descriptives and Sample Characteristics (N = 72)

Variables	All	Young women	Young men
Activity, number of valid days[a], *M* (*SD*)	5.38 (2.00)	6.04 (1.56)*	5.00 (2.16)*
Mean accelerometer wear time[b], hours (*SD*)			
Weekday	15.93 (2.35)	16.76 (2.13)*	15.49 (2.37)*
Weekend day	15.40 (2.25)	15.93 (2.00)	15.01 (2.38)
Mean activity[b], hours (*SD*)			
Weekday	1.28 (0.48)	1.05 (0.32)*	1.41 (0.52)*
Weekend day	0.92 (0.75)	0.73 (0.61)	1.06 (0.83)
Depressed affect, number of diaries[c]			
Next-morning, *M* (*SD*)	6.75 (0.83)	6.88 (0.43)	6.67 (1.00)
Same-evening, *M* (*SD*)	6.13 (1.59)	6.88 (0.33)*	5.71 (1.87)*
Depressed affect, daily rated[b], *M* (*SD*)			
Next-morning			
Weekday	0.49 (0.65)	0.45 (0.58)	0.52 (0.71)
Weekend day	0.39 (0.54)	0.43 (0.55)	0.38 (0.55)
Same-evening			
Weekday	0.47 (0.55)	0.47 (0.56)	0.47 (0.55)
Weekend day	0.39 (0. 57)	0.45 (0.66)	0.36 (0.51)
No intraindividual variation of depressed affect[d], %			
Next-morning			
Weekday		20.00	32.43
Weekend day		47.06	47.37
Same-evening			
Weekday		24.00	35.29
Weekend day		38.89	57.89
Depressed affect, retrospectively rated[e], *M* (*SD*)	15.24 (7.85)	15.96 (8.47)	14.88 (7.62)
Depressed[f], %	11.80	12.00	11.90
Mean age, years (*SD*)	17.36 (3.38)	16.27 (2.59)*	18.01 (3.67)*
Gender, %		36.62	63.38
Grade			
7-9, %	30.99	36.00	28.89
10-12, %	69.01	64.00	71.11
Higher education entrance qualification, intended %	93.06	88.46	97.78
Other country of origin than Germany, %	12.86	12.00	13.33
Parents with another country of origin than Germany[g], %	41.43	32.00	46.66
Parents with a higher entrance qualification[g], %	60.29	62.50	59.09
Parents with a university degree[g], %	40.91	37. 50	42.86

Note. Activity = moderate-to-vigorous physical activity measured by accelerometers. [a]Valid day: accelerometer wear time ≥ 10 hours per day. [b]Person mean of accelerometer wear time, activity, and depressed affect (measured through POMS-15, scale range: 0-4).

[c]Maximum number of diaries amounts to seven morning and evening diaries each. [d]Based on intraindividual standard deviations (ISDs); percentage of adolescents showing no intraindividual variation of depressed affect (e.g., only ratings of being *moderately depressed*) across all studydays. [e]Depressed affect was retrospectively reported for the study period on Day 8 (measured through CES-D, scale range: 0-3). [f]Based on CES-D cut-off ≥ 23. [g]Information refers to at least one parent.
* Statistically significant gender differences ($p < .05$).

Table 2

Gender, Weekday vs. Weekend Day, and Physical Activity as Predictors of Next-Morning and Same-Evening Depressed Affect, Fixed and Random Effects

	Depressed affect					
	Next morning: Time-lagged prediction (N = 67)			Same evening: Same-day link (N = 68)		
Fixed effects of predictors	Estimate		*SE*	Estimate		*SE*
Intercept γ_0	0.46	*	0.11	0.44	*	0.19
Men γ_1	0.02		0.15	-0.01		0.12
Weekend γ_2	-0.07		0.10	-0.04		0.11
Men x weekend γ_3	-0.07		0.13	0.05		0.16
Activity γ_4	-0.24	*	0.11	-0.17		0.14
Activity x men γ_5	0.26	*	0.13	0.29		0.17
Activity x weekend γ_6	0.37	*	0.17	0.19		0.19
Activity x men x weekend γ_7	-0.26		0.23	-0.34		0.26
Random effects (variances)						
Level 2 (between-person)						
Intercept	0.25	*	0.06	0.12	*	0.04
Level 1 (within-person)						
Residual	0.28	*	0.03	0.35	*	0.03
AR1 ρ	0.19	*	0.08	0.14		0.08

Note. γ_0 = average depressed affect for young women on weekdays (intercept); γ_1 = difference in average depressed affect between young men and women on weekdays; γ_2 = weekdays-weekend days difference in depressed affect for young women; γ_3 = Do young men differ in their weekdays-weekend days difference in depressed affect from young women? γ_4 = activity-affect link in young women on weekdays; γ_5 = Do young men differ in activity-affect link on weekdays from young women? γ_6 = Do young women differ in the activity-affect link between weekdays and weekend days? γ_7 = Do young men differ in activity-affect link between weekdays and weekend from young women? Men = young men (0 = young women, 1 = young men); Weekend = weekend day (0 = weekday, 1 = weekend day); Activity = moderate-to-vigorous physical activity measured by accelerometers, centered at the person mean, in 60 min units; Estimate = unstandardized regression coefficients; *SE* = standard error.
* $p < .05$.

6. Affirmation

Ich versichere, dass ich meine Dissertation

"Physical Activity in Adolescents — Barriers and Impact on Depressed Affect"

selbstständig ohne unerlaubte Hilfe angefertigt und mich dabei keiner anderen als der von mir ausdrücklich bezeichneten Quellen und Hilfen bedient habe.

Die Dissertation wurde in der jetzigen oder einer ähnlichen Form noch bei keiner anderen Hochschule eingereicht und hat noch keinen sonstigen Prüfungszwecken gedient.

Hamburg, 12.04.2016 Nadine Langguth